PRE-EDITED

1998 International Oil Palm Conference

Commodity of the past, today, and the future

September 23-25, 1998

Sheraton Nusa Indah Hotel, Bali, Indonesia

EFFECT OF DROUGHT AND HAZE ON THE PERFORMANCE OF OIL PALM

J.P. Caliman[1] and A. Southworth[2]

1) CIRAD-CP - BP 5035 - 34032 MONTPELLIER Cedex 1 – FRANCE
2) PT. SMART Corporation Gedung BII - Lt 7 - Jl. DIPONEGORO No 18 - 20152 MEDAN - INDONESIA

150 Years of Oil Palm in Indonesia

Jointly organized

by

Indonesian Oil Palm Research Institute
(IOPRI)

Indonesian Palm Oil Producers Association
(GAPKI)

EFFECT OF DROUGHT AND HAZE ON THE PERFORMANCE OF OIL PALM

J.P. Caliman[1] and A. Southworth[2]

1) CIRAD-CP - BP 5035 - 34032 MONTPELLIER Cedex 1 – FRANCE
2) PT. SMART Corporation Gedung BII - Lt 7 - Jl. DIPONEGORO No 18 - 20152 MEDAN - INDONESIA

AG
12

EFFECT OF DROUGHT AND HAZE ON THE PERFORMANCE OF OIL PALM

J.P. CALIMAN * - A. SOUTHWORTH **

*: CIRAD-CP
Po Box 1348 – 28000 Pekanbaru – Riau – Indonesia
Or : c/o CIRAD-CP – BP 5035 – 34032 Montpellier – France
Email: caliman@indo.net.id
caliman@cirad.fr

**: PT SMART CORPORATION
BII Plaza. Tower 2.Floor 28 – jl M.H. Thamrin. Kav 22 – 10350 Jakarta – Indonesia
Email: asouthw@ibm.net

ABSTRACT

One of the most important events occurring during 1997, which affected oil palm cultivation, is related to the "El Niño" phenomenon. This climatic incident resulted in a dramatic drought in many parts of South East Asia. Subsequently uncontrolled development of fires in Indonesia led to the development of haze which spread across neighbouring countries of the region.

The first part of the paper presents a tentative estimate of the impact of the drought on future yields (1998 and 1999) of the palms, based on several studies made in the recent past in West Africa and Indonesia. These studies used statistical models about the relationship between the water deficit calculated on a determined period, and the subsequent production of the palms. Seasonal variations are considered, in relation with periods of particular susceptibility of inflorescences during their development. It appears that the age of the palms is also an important factor to take into consideration.

The second part of the study deals with the impact of the haze on the performance of oil palms. An estimate of the negative effect on yield is proposed, using an agro-climatic model set up by CIRAD's physiologists. A major short-term impact of the haze was the significant negative effect on oil extraction rate (OER) observed at factories. A statistical model of OER variations according to global radiation is presented and discussed. Although drought and haze occurred during the same period, a tentative split of the corresponding effects has been made.

Key words: oil palm, drought, haze, yield, oil extraction rate.

INTRODUCTION

1997 will remain in everyones memory as the year of El Niño. This climatic incident, known by meteorological specialists for decades reached a level not yet recorded in the past. It resulted in a dramatic drought in many parts of the world, particularly in South East Asia. Subsequently, as burning is still a common practice used by Indonesian farmers to clear the land, these dry conditions led to uncontrolled fires and a thick haze that spread across neighbouring countries in the region.

❑ IMPORTANCE OF THE DROUGHT

Among the climatic factors, water supply is considered as the most important for the production of oil palm. Hartley (1988) defined the optimum conditions, with an annual rainfall figure reaching 2000 mm, with a regular monthly distribution.

Prolonged water supply deficits results in increasing vegetative disorders as described by Maillard et al. (1974) : accumulation of unopened leaves, premature drying out of lower leaves, broken green leaves, drying out of bunches, toppling of the entire canopy. In extreme conditions, the palm may even die.

Before this extreme situation, water deficit has a negative impact on oil palm sex differentiation. It also increases the rate of female inflorescence abortion and reduces the plant growth. As a result the yield of the palms drops during several months after the drought. Negative impact on the oil content of the fruit have also been reported by Ochs and Daniel (1976). This is the consequence of a reduction of the photosynthetic activity in the palms, caused by a progressive stomata closing as the soil's water reserve dries up (Dufrene et al., 1990).

Water deficit situations are often encountered in West Africa. In Ivory Coast for example, a more or less severe drought is observed quite every year, with an annual water deficit generally higher than 200 mm, and reaching 500 - 600 mm in exceptional cases. In Benin, Pobe Research Station is located in an even more critical area with an average annual water deficit reaching ± 550 mm, and annual variations between 300 and 900 mm (CIRAD-IRHO, 1992).

In South East Asia, moderate drought is frequently observed in the southern Thailand. In Indonesia, the province of Lampung (Sumatra) is quite particular: the drought is not an annual climatic event, but it reaches levels as high as 400 - 600 mm on a regular basis (Figure 1). The frequency of these dry periods seems to have increased over the last decades : from once every five years in the seventies to quite every four years in the eighties. Now, since the start of this decade, severe droughts have been recorded every three years.

❑ A NEW FACTOR: THE HAZE

The long period of haze observed in Sumatra and Kalimantan (Indonesia) from August to October 1997 was a new factor faced by farmers. It had certainly a negative impact on the performance of the palms, following a significant reduction in global radiation. This may have reduced the photosynthetic activity of the palms, as shown by Corley (1976) and Dufrene et al. (1990) who identified the close relation between carbone dioxyde assimilation and the photosynthetic active radiation received by the canopy.

Until now little has been reported on the influence of such conditions in the nature. Except for the possible negative impact of the haze caused by the eruption of the Pinatubo volcans in the Philippines.

The purpose of this article is to try to forecast the impact of the drought on future oil palm yields, based on several studies made in the past in West Africa and Indonesia, together with some new findings. The second part deals with the effect of the haze on the performance of the palms. A tentative estimate of the negative impact on the yields will be proposed using an agro-climatic model built up by physiologist (Dufrene et al., 1990). An important finding concerns the drop of oil extraction rate (OER) observed in factories in areas affected by the haze. A tentative explanation will be proposed.

A - PRODUCTION OF FRESH FRUIT BUNCHES

❑ IMPACT OF THE DROUGHT

In the sixties, there was major expansion of oil palm cultivation in West Africa, especially in the Ivory Coast. Land evaluation was based on tables showing the yield potential according to type of soils and water deficits (Olivin, 1968). In that tables, the negative impact of 100 mm of water deficit was estimated at about 10 to 15% on good soils, depending on the intensity of the drought. On poor soils, with low water storage capacity, 100 mm of water deficit was supposed to reduce the yield by more or less 20%.

The assessment made by Ochs and Daniel (1976), based on observations made in the Ivory Coast, Dahomey (now Benin) and the Cameroons, was close to Olivin's proposal, with a negative impact of 10 to 15% of the yield potential per 100 mm of water deficit, depending also on the intensity of the drought.

In the eighties, because of dramatic droughts in West Africa, there was a requirement for more accurate forecastings. Statistical models of the impact of water deficit on the yield were therefore set up. These models were developed using observations made on specific planting materials (Dufour et al., 1988; Caliman, 1985); These models use a water deficit calculated over the 3 years prior to harvesting. They were then applied to whole estates. According to these statistical models, a variation of 100 mm in the annual water deficit, within a range of 0 to 500 mm, causes yields to vary by 10% of potential production (i.e. with no water deficit).

Similar findings were made in Lampung (Caliman, 1992). In this case, the best statistical model are obtained by taking individual annual water deficits over a period of two or three years, instead of a cumulative water deficit as in West Africa. This difference may be due to the fact that in Lampung, droughts are observed periodically (every 3 to 5 years) with little overlapping of the impact of successive droughts, instead of every year in West Africa. The specific situation in Lampung with "isolated drought", makes it possible to forecast the effect of a drought on the following three years. Indeed statistical models indicates that 100 mm of water deficit recorded in year n has a negative impact on the yields during the following three years :

- year n+1: - 8 to - 10 % of yield potential[1] (Figure 2).
- year n+2: - 3 to - 4 % of yield potential.
- Year n+3: slight negative impact, but significant when the drought in year n is very severe (≥ 400 - 500 mm).

These models are quite easy to use as it is only necessary to multiply these percentage by the level of water deficit recorded, to forecast the decrease in yield. The accuracy is between 5 to 10% depending on the accuracy of the data obtained, the length of the periode and the range of parameters.

Nevertheless we need to keep in mind that statistical models are only accurate within the conditions (water deficit range, age and type of palms) they have been built on. It seems for example that the age of the palms is an important parameter to take into consideration : old palms seem slightly less affected by drought than young mature palms.

The status of the palms during the drought is also an important factor which may modify the impact of the drought : low yielding palms during periods of water deficit, resulting in low exportations and requirements, will be less affected.

Lastly, the presence of a water table in the soil modifies the actual water deficit, as this allows a supply of water to the palms, even during a dry season.

The use of this statistical model on an estate located near Palembang (South Sumatra) fits quite well with the yields actually recorded (Figures 3 and 4). In that estate, only the palms planted in 1989 do not reach the forecasted levels of production. Nonetheless

[1] Yield potential = yield during no water deficit.

they follow the trend expected according to water deficit calculation (Table 1). A revised potential of yield needs to be proposed in that case, about 25% below the current one.

TOWARDS FORECASTING THE YIELD ON A MONTHLY BASIS

One of the consequences of a dry season lasting several months is to induce important seasonal variations in yields. Without any water deficit, yields are more or less uniform throughout the year, with monthly production between ± 6-7% until ± 11-12%. Water stress during long periods modifies the physiology of the palms, with impact on the rate of bunch abortion (a short term effect on yield) and inflorescence differentiation (a long term effect on yield). As a result we observe periods with low crop, where monthly production represents as low as 1 to 2% of the annual production, and periods where monthly production represents up to 20 to 30% of the total annual yield. In extreme areas like in Benin, the full production is often concentrated within several months only. It is not worthwhile dwelling on the problems faced by estates and factory management in such cases.

Therefore ones can understand the interest of Planters and Mens involved in oil palm and palm oil business, in being able to forecast yields on a monthly basis.

During his study, Frere (1986) made a chronological analysis of monthly yield[1] and climatic parameters recorded at Dabou (Ivory Coast). He found three periods where production was particularly sensitive to water stress :

- the first one was between 7 and 13 months before harvesting. This corresponds to the aborting period;
- the second is between 19 and 24 months. It may correspond to the fast growth of the leave supporting the inflorescence;
- the third was between 30 and 33 months before harvesting. This could corresponds to the sex differentiation period.

Based on this observation, he proposed a statistical model of the monthly production including water deficit parameters during these periods. The useful radiation index from month 24 to 27 before harvesting was also part of the model. The model obtained had a good coefficient of determination ($r^2 = 0.72$). The main problem of this model is that final forecasting can only be done 6 months before the end of the harvesting year. Therefore Frere proposed an other model, working at the beginning of each campaign, with still good accuracy ($r^2 = 0.68$).

[1] Actually on the residue of the yield after taking account of the seasonal variations.

We have obtained similar results by making a chronological statistical analysis of data recorded in Lampung. We use either the water deficit or the water reserve in the soil as a water stress parameter. From this, we find three similar periods of sensitivity of the palms (Figure 5a & b) :

- between ± 4-5 and 10 months before harvesting;
- between ± 18 and 22 months before harvesting;
- between ± 30 and 33 months before harvesting.

The most important variation is that the first period seems to have moved ±3 months towards harvesting, or approximately one month after anthesis.

Figure 6 presents the history of the 1998 harvesting campaign in Lampung: for every harvesting month, we have placed the 3 main periods of palm sensitivity as well as the period where the drought usually occurs. We observe that the first seven months of the year (January until July) are the most affected by the drought as there is a superposition of the critical periods for the palms and the dry season during the previous years. Indeed the cumulated water deficit observed during the sensitive periods are very high during these months. March, April and May are the most affected months.

On the other hand, the period from August until December is less affected by drought (especially September and October). But according to this sequence, November and December can present lower yields when there is a very dry season during the same year.

This timing seems to be confirmed in Lampung by the calculation of the correlation between the monthly yields and the total water deficit observed during the current or the previous year (Figure 7).

Finally, the models set up for Lampung shows that the first critical period (4-5 to 10 months before harvesting) has the biggest impact on the yield :

- Planting 1970 – 1971:

$$\mathbf{Yield/month_{Jan\text{-}July} = 1.75 - 0{,}0030\ WD_{-5,-10} - 0{,}0014\ WD_{-18,-22} - 0{,}0018 WD_{-30,-33}}$$

(r = 0.72 σ residue = 0.58)

- Planting 1974 – 1975:

$$\mathbf{Yield/month_{Jan\text{-}July} = 1.92 - 0{,}0034\ WD_{-5,-10} - 0{,}0009\ WD_{-18,-22} - 0{,}0006 WD_{-30,-33}}$$

(r = 0.65 σ residue = 0.67)

where $WD_{-5,-10}$ is the water deficit cumulated from 5 to 10 months before harvesting.

When the water deficit during that period increases by 100 mm, the production falls by 15 to 20% during the corresponding month.

Using these relations we observe that the impact of the second and third period are around 5-10% and 3-10% respectively. Nevertheless the intensity of the negative impact depends on the two following factors and their combinations :

- the level of the crop during the drought. High yielding palms will be more affected than low yielding one;
- the rainfall conditions during the campaign following the drought.

The pattern of yield variations observed in Lampung during the months of November is a good illustration of these phenomenons (Figures 8 a & b). When the water deficit is in the low to medium range (0-300 mm) during two consecutives years, the annual performance of the palms are lower (lowest line in Figure 8b) compared to palms that have supported high water deficit during the previous year. In that case we observe a drop of the yield (certainly through abortion of bunches) during the months of November and December just after the drought. These low yields last until the third quarter of the year. Then, high production are observed from October to December, i.e. one year after the end of the drought.

The performances of the palms in the Palembang area (Pangkalan Panji estate) confirmed the interest of this model (Table 2). For the 1975 plantings, the water deficit recorded in 1991 (387 mm), 1994 (392 mm) and 1997 (614 mm) had a negative impact during the following months, from October/November until July/August. In order to assess the rate of the negative impact, we have chosen the 1993 performance as a the yield potential. Indeed 1993 presents a good annual yield, with a rather homogeneous monthly distribution of production. Nonetheless it appears that for several months the 1993 yield was lower than others years.

From March until May (the bunches harvested during these months have supported the highest water-stress recorded during the first critical period), the level of the impact of the drought observed in 1991, 1994 and 1997 varies between 13 and 23 % each 100mm of water deficit observed during the first critical period (table 2). These results fit well with the model proposed previously. For younger palms (planting 1987), the results are also satisfactory. In this case the impact reaches 13 to 18 %. The main difficulty is to estimate the monthly potential of production in order to make good comparisons.

As a conclusion, the model for annual yield forecast using water deficit works quite well: 100 mm of water deficit reduce the annual yield potential by 8-10 % during the following year, and by 3-4 % the second year after the drought.
On a month basis, a model can also be drawn down, based on the water deficit recorded during three sensitive periods. The first period (4 to 10 months before harvesting) has the highest impact on the yield. This model has been confirmed from March to May in the condition of South Sumatra and Lampung, where the drought

usually occurs between July and November. In this case, an increase in the water deficit by 100 mm reduces the monthly yield potential by 15 to 20 %.
We still have to confirm that this model is working also from January to June-July. That point should no present major difficulties. On the other hand, some more calculations have still to be done to build up a model to forecast yield from October to December. For these months, it might be necessary to work with two models, depending on the water stress observed during two consecutive years. We are still working on that point.

▫ IMPACT OF THE HAZE

The long drought in Sumatra led to a multiplication of uncontrolled fires. Then a thick haze was observed from August until October, with a pic in September and October. As a result the global radiation measured in September-October at Libo Research Station (Riau - Sumatra) was 30% lower than the average conditions mentioned by Lamade (1996) for North Sumatra (Table 3).

We have tried to estimate the effect of this haze on the future yields of the palms in Riau area, as Dufrêne et al. (1990) shown the close relationship between the photosynthetic activity of the palms and the photosynthetic active radiation (PAR) received by the conopy. For that purpose we have used the SIMPALM software (CIRAD-CP, 1995) for a simulation of the photosynthetic activity of the palms in normal conditions (without haze) and in actual conditions. All calculations have been done on a week basis.

Among the parameters which have to be input in the program, five have been specified in order to fit with our local conditions :

- the maximum assimilation (Amax) has been modified weekly, taking account of the theoretical variation of the stomatal conductance (CIRAD-IRHO, 1989) induced by the soil water reserve evolution calculated in that area.
- Height of palms: 5.30 m (corresponding to ± 9 years old palms).
- Number of leaves: 40
- Planting density: 136 palms/ha.
- Temperature: 26.2 °C (average temperature at Libo).

All other parameters of the model have remained unchanged as no precise value could support any modification. We estimate that any change of these parameters would not have modified this type of comparative study.

Table 4 presents the data entered in the software and the results of the simulation, with or without the haze. The difference represents an equivalent of 1.3 tonnes of fresh fruit bunches per hectare. This quantity might appear quite small, but this is the consequence of the drought, which acts as a main limiting factor. Without any water deficit, the difference would have reached 4.7 t FFB/ha.

An other point related to the haze and mentioned by Lamade (1997) is the increase of the CO_2 concentration of the atmosphere (500 ppm compared to a usual 350 ppm). This parameter may have increased the photosynthetic activity of the palm during the same period.

Nevertheless, the following chapter presenting the impact of the haze on the oil extraction rate observed in oil palm factories shows that the balance is still negative.

B – OIL EXTRACTION RATE: IMPACT OF DROUGHT AND HAZE

During September and October 1997, the oil extraction rates (OER) in several Sinar Mas's factories dropped to their lowest values ever recorded. In Sam Sam factory (Riau - Indonesia) for example, where the average OER from the beginning of operations in August 1993 until December 1996 was 24.0%, the OER has fallen to 22.1% in October 1997. These results cannot be explained by a seasonal variation of the characteristics of the bunches (Table 5). Also the relatively high quantity of unripe bunches observed during that period cannot fully explain these low OER (Table 6).

Actually OER declined slightly from June/July 1997, with a sharp drop starting mid-September 1997 (Figure 9).

The rainfall recorded at Libo estate (Table 3) reflects the drought observed throughout Indonesia during this period. At the same time, and as a result of these dry conditions, forest and bush fires expended rapidly, with a thick haze covering a major part of Sumatra and Kalimantan. As mentioned previously, the sunshine duration and its global radiation measured in the newly installed weather station at Libo Research, shows clearly the negative impact of the haze. The intensity of the two phenomenons (drought and haze) leads us to consider these parameters as a possible cause of the decrease of OER.

In this chapter, we propose to evaluate the existence and importance of these hypothetical relations in order to diagnose the situation, and to build a statistical model that could be used for making future forecast.

Materials and methods

The study was developed using OER data recorded at Sam Sam factory. The daily data was compiled on a week basis, which was more representative of the actual conditions and the weekly management of the factory itself (maintenance, ...).

Daily climatic data has been recorded at Libo estate since the beginning of the period under study (rainfall) or at Libo Research Station from July 1997 (sunshine duration and global radiation). Sunshine duration recorded at Pekanbaru airport has been used for studies involved before July 1997.

In order to quantify the water stress affecting the palms, the soil water reserve (SWR) was calculated using the IRHO method (Surre, 1963) adapted for a computation on a week basis[1].

A chronological analysis of the set of data (OER, global radiation, soil water reserve) was undertaken in order to determine the correlations between OER and global radiation or SWR. GR was considered between 1 until 5 weeks before harvesting, as a previous study has shown little impact before that time. Also a modeling done on the results of Mohankumar et al. (1994) shows that at least 70% of mescocarp oil is synthesized within the last 5 weeks before harvesting. SWR was considered between 1 and 26 weeks before harvesting, considering the period between anthesis and harvesting. The aim of this analysis was to determine the period affecting OER, and then to set up a statistical model for the variation of OER by a progressive introduction of the different significant parameters.

Taking account the availability of the local data, the model was set up on a period starting in August 1997. Then it was applied from January 1994 until April 1998.

Results and Comments

From August 1993 (the date when the factory started operating) until the end of April 1998, the average OER reached 23.9%. Ninety percent of the weekly values are higher than 23%. But five negative pics can be observed (Figure 10). We shall make some coments about them at in the second part of the article. Our first interest concerns the trend of OER during 1997 which shows a progressive negative curve starting in June with a minimum in September (Figure10).

---

[1] - ETP = 35 mm/week when 1 or 2 days rainfall per week.
- ETP = 28 mm/week when ≥ 3 days rainfall per week.
- Maximum soil water reserve = 200 mm.

Due to the short period of data observed (only 4 full years since the beginning of operations at the factory) it was not possible to define any clear seasonal variation of OER. Therefore the analysis was done with the original data, without any correction.

The correlations obtained between OER and global radiation, and between OER and SWR are summarized in figures 11 a & b:

- OER is highly correlated with the global radiation measured from week 1 until week 4 before harvesting. The relationship during the fifth week before harvesting is still positive, but with a lower degree of significance. Figures 12a to 12e show the pattern of the relationship between OER and GR, indicating the relatively wide distribution during week 5.
- OER is also correlated with SWR. But we observe two periods of influence:
    - during the first period, from week 5 until week 12 (i.e. 1 to 3 months before harvesting), SWR is positively correlated to OER.
    - meanwhile during the second period, from week 19 until week 26 (i.e. 4 to 6 months before harvesting), SWR is negatively correlated to OER.

It seems clear that the relation between OER and global radiation is closer than the relation between global radiation and the soil water reserve (Table 7). A progressive regression has confirmed this assumption.

The pattern of the repartition of the points presenting OER versus global radiation cumulated during 4 weeks before harvesting indicates (Figure 13) :

- the relation is not exactly linear, but tends towards an asymptotic value.
- the points seem to be distributed according to two phases; a "negative phase" corresponding actually to a consistent decrease[1] of global radiation with time; a "positive phase" with higher OER, corresponding actually to a consistent increase of global radiation with time.

That phenomenon means that below a global radiation of 400 - 440 $MJ/m^2/4$ weeks (i.e. 14.3 - 15.7 $MJ/m^2/day$), the OER is more affected by a low level of global radiation when this factor is consistently decreasing. In other terms, we can conclude that oil in the mesocarp which is not synthesized at a certain time because of low global radiation, can still be synthesized later, before harvesting, if the radiation increases.

---

[1] - A consistant negative periode means : a period of successive weeks with global radiation lower than 100-110 $MJ/m^2/week$ (14.3 - 15.7 $MJ/m^2/day$) and a general decreasing trend (including a short temporary increase), including also a following period of stable low values.

- A consistant positive periode means : a periode of successive weeks with global radiation higher than 100-110 $MJ/m^2/week$ (14.3 - 15.7 $MJ/m^2/day$) or a periode of successive weeks with lower value of GR but showing a general increasing trend (including a short temporary decrease).

Two curves have been fitted for the respective phases :

- Negative phase

$$\mathbf{OER_{week} = 24.59 - 42.45 \exp(-0.0091\ GR_{4\ weeks}).}$$

r^2 = 0.99 (number of observations : 10)
standard deviation of the residus = 0.29

- Positive phase

$$\mathbf{OER_{week} = 24.98 - 45.66 \exp(-0.0106\ GR_{4\ weeks}).}$$

r^2 = 0.99 (number of observations : 29)
standard deviation of the residus = 0.37

Figure 14 shows a comparison between actual and calculated OER using these statistical models. The concordance of the simulation is quite remarquable. The standard deviation of the residus is 0.33 only.

The very little variation observed between the actual OER to the calculated one using these models based on global radiation alone, would mean that water stress (expressed by the soil water reserve) has very little impact on OER. Nevertheless we have to keep in mind that during that periode there were a close relation between the two climatic parameters : the haze occurred because of the severe drought. Therefore a negative impact of poor SWR may have been already confounded with the impact of the global radiation.

A tentative effort has been made in order to precise any supplementary impact of the drought : the correlations between the residues of EOR (difference between actual and calculated OER) and the SWR have been calculated. The results shown figure 15 indicate two periods of influence, similarly to the previous observations made at the beginning of the study, but with a slight different timing :

- during weeks 8 and 9 (i.e. ± 2 months before harvesting) the SWR has a positive impact on OER.
- during weeks 17 to 20 (i.e. ± between 4 and 5 months before harvesting) the SWR has a negative impact on OER.

The coefficients of correlation between OER residues and SWR cumulated on the corresponding periods are presented table 8.

The relation obtained between OER (residues) and SWR are close enough to be incorporated in a new model :

- during a negative phase

$$\mathbf{OER_{week} = 24.56 - 42{,}45 \exp(-0.0091\ GR_{4\ weeks}) + 0.0016\ SWR_{P1} - 0.0008\ SWR_{P2}}$$

- <u>during a positive phase</u>

$$OER_{week} = 24.95 - 45{,}66 \exp(-0.0106\ GR_{4\ weeks}) + 0.0016\ SWR_{P1} - 0.0008\ SWR_{P2}$$

Where :

- $GR_{4\ weeks}$ = global variation cumulated during the four weeks before harvesting.
- SWR_{P1} = soil water reserve cumulated during weeks 8 and 9 before harvesting.
- SWR_{P2} = soil water reserve cumulated between the 17 and the 20 weeks before harvesting.

Figure 16 shows a comparison between the actual OER and the calculated one with this model. Compared to the previous model using global radiation exclusively, some improvement can be observed, specially between February and April 1998. The standard deviation of the new residues obtained (OER actual minus OER calculated) is improved to 0.30.

Application of the model on a longer period : January 1994 to April 1998

The application of the model since the opening of the factory, requires observations about global radiation and soil water reserve. Global radiation measurements started near the site (Libo Research) only in July 1997. In order to overcome this problem we have used sunshine duration measurements made at Pekanbaru airport. These data have then been transformed into GR values after fitting a relation between the two climatic factors (sunshine - GR). For that purpose, we have used observations recorded during the period July 1997 - April 1998 at Libo Research Station (Figure 17). It can be noticed that this relation is not linear.

Figures 18 shows the comparison between the actual OER observed at the factory and the calculated one. The main trends of the two curves are similar, but the accuracy of the model is much lower compared to the first study (period August 1997 - April 1998). The standard deviation of the residues reaches 0.80. This result is certainly related to the low accuracy of the GR values obtained, certainly due to the "poor" representativity of the Pekanbaru records for Libo/Sam Sam area.

A tentative to build a new model based on the full set of data (from January 1994 to April 1998) was not satisfactory, in terms of accuracy, certainly for the same reason.

One important concern is the presence of 5 negative pics with low OER comprised between 22 and 23 %. Considerations about the quality of the bunches (percentage of unripe and poor pollinated bunches), gives some explanation (Table 9).

Each negative pic is the result of a bad quality crop, either high unripe bunches percentage, either bad pollination of the bunches. The very high rate of bunches coming from new mature palms (2-4 years old) with low oil content, can explain the bad quality of the crop during pic 5. For the others pics (1, 2, 3 and 4) no information are available about the origine of the crop.

CONCLUSION

The frequency of the drought observed in the South of Sumatra (Lampung and Palembang areas) allows us to get some complementary informations about the impact of water stress on the production of oil palms. Statistical models indicates that 100 mm of water deficit reduce the yield by 8 to 10% the following year, and by 3 to 4% the second year. Actually it has to be mentioned that part of this impact can be observed the same year, due to the timing (calendar) of the occurrence of the drought.

It has been confirmed that there are three periods of sensitivity to water stress before harvesting. Based on this point a statistical model of the monthly production has been set up for the Sumatra conditions. It indicates that 100 mm of water deficit during the corresponding sensitive period, reduce the yield by 15 to 20% per month between February to June. In November and December following the drought, we observe an impact of 10 to 15% of the yield potential, per 100 mm of water deficit. But for these two months, the potential level depends on the climatic conditions of the previous year as well.

The use of SIMPALM software for the simulation of the yield of the palms gives a rough estimation of the probable impact of the haze. In Riau area, we could expect a decrease of the yield by 1.3 t FFB/ha.

It is interesting to see that the model for the OER proposed in this study indicates that in the same area (RIAU), the OER has fall down by ± 2 points during the haze, i.e. an equivalent reduction of yield of 2 t FFB/ha for un production of 25 t FFB/ha. This last model shows that the drought has relative little impact on OER. That point will have to be precised in the future.

References

CALIMAN JP (1985). Yield forecasting for oil palm at Dabou. Internal report.

CALIMAN JP (1992). Relation production - water deficit at Bekri (Lampung). Internal report MR-AGRO21. Marihat Research Station.

CIRAD-CP BIOMETRIE, DUFRENE E (1995). Software: Simulation de l'assimilation photosynthetique, de la respiration, de la repartition des assimilats, du bilan hydrique, et de la production de l'agrosysteme palmeraie.

CIRAD - IRHO (1989). Annual report 1989 - Oleagineux. 44 (4). 220p.

CIRAD - IRHO (1992). Annual report 1992. 456 p.

CORLEY RHU (1976). Photosynthesis and productivity. In: Oil palm research. Elsevier Scientific Publishing Company. Amsterdam. 55 - 76.

DUFOUR O, FRERE JL, CALIMAN JP, HORNUS P (1988). A simplified method for forecasting oil palm yields based on climatology. Oleagineux. 43 (7). 271 - 278.

DUFRENE E, OCHS R, SAUGIER B (1990). Photosynthese et productivite du palmier a huile en liaison avec les facteurs climatiques. Oleagineux. 45 (8-9). 345 - 352.

FRERE JL (1986). Relation climat - production d'une palmeraie en Cote d'Ivoire. Memoire de fin d'etudes. Faculte des sciences agronomiques de Gembloux (Belgique). 75p.

HARTLEY CWS (1998). The oil palm. Third edition. Longman group limited. London. New York. 761 p.

LAMADE E (1997). Preliminary analysis for physiological forecasting for oil palm yield in Sumatra under temporary water deficit and radiation constrainot. Under press. 2p.

LAMADE E, BONNOT F, POLEOENGAN Z (1996). Modelling photosynthesis and stomatal responses of oil palm clones to environmental conditions in North Sumatra (Indonesia). Implication for plant breading. In: PORIM. Proceedigns of the 1996 PORIM international palm oil congress. Kuala Lumpur. PORIM. P 87-96.

MAILLARD G, DANIEL C, OCHS R (1974). Analyse des effets de la secheresse sur le palmier a huile. Oleagineux. 42.29 (8-9). 397 - 404.

MOHANKUMAR C, ARUNUGHAN C, KALEYSA RAJ R (1994). Histological changes in mesocarp of oil palm (Elaeis Guineensis) fruit during development. J. Food Sci. Technol. Vol 31 (1). 91-21.

OCHS R, DANIEL C (1976). Research on techniques adapted to dry regions. In: Oil palm research. Elsevier Scientific Publishing Company. Amsterdam. 315 - 330.

OLIVIN J (1968). Etude pour la localisation d'un bloc industriel de palmiers a huile. Oleagineux. 23 (8-9). 499 - 504.

SURRE C (1968). Les besoins en eau du palmier a huile : calcul du bilan de l'eau et ses applications pratiques. Oleagineux. 23. (3). 165-167.

Table 1 - Pangkalan Panji Estate:Yields recorded in planting 1989

Year	Water deficit (mm)	Yield (t FFB/ha) forecasted	actual	difference
1993	90	-	-	-
1994	390	-	-	-
1995	0	16.3	12.3	- 26%
1996	0	22.0	16.3	- 26%
1997	615	26.0	20.3	- 22%

Table 2 - Production (t FFB/ha) at Pangkalan Panji estate (Palembang)

Year	Age	Jan	Feb	Mar	Apr	May	Jun	Jul	Ags	Sep	Oct	Nov	Dec	total	water deficit (mm)
Planting 1975															
1991	16	0.93 5 -	1.07 6 -	0.97 6 -	0.89 5 -	1.36 8 -	1.71 10 -	2.10 12 -	1.74 10 -	1.87 11 -	1.84 11 -	1.42 8 -	1.32 8 -	17.2	387
1992	17	1.04 7 -	0.46 3 -	0.38 3 **17**	0.27 2 **23**	0.28 2 **23**	0.39 3 -	0.29 2 -	0.68 5 -	1.63 11 -	2.19 **15** -	3.01 **21** -	3.85 **27** -	14.5	0
1993	**18**	**1.34** **5** -	**1.64** **7** -	**1.13** **5** -	**2.13** **9** -	**2.42** **10** -	**2.39** **10** -	**1.97** **8** -	**2.89** **12** -	**3.27** **13** -	**2.30** **9** -	**1.73** **7** -	**1.59** **6** -	**24.8**	0
1994	19	1.17 5 -	1.45 6 -	1.15 4 -	2.49 10 -	1.93 7 -	3.46 13 -	2.90 11 -	2.25 9 -	1.28 5 -	2.24 9 -	3.68 14 -	1.75 7 -	25.8	392
1995	20	1.21 6 -	0.90 4 -	0.47 2 **15**	0.66 3 **18**	0.62 3 **19**	0.50 2 -	0.82 4 -	1.72 8 -	2.78 13 -	2.94 **14** -	5.08 **23** -	4.01 **18** -	21.7	0
1996	21	0.94 4 -	0.93 4 -	1.11 5 -	1.15 5 -	1.53 7 -	1.79 8 -	1.68 8 -	2.06 9 -	3.34 15 -	3.74 17 -	2.20 10 -	1.55 7 -	22.0	0
1997	22	1.11 5 -	0.75 3 -	1.18 5 -	1.69 8 -	2.86 13 -	2.19 10 -	3.91 18 -	3.01 14 -	2.08 9 -	1.85 8 -	1.03 5 -	0.52 2 -	22.2	614
1998	23	0.40 2 -	0.29 2 -	0.20 1 **13**	0.14 1 **15**	0.10 1 **16**	0.27 1 -	0.29 1 -	2.26 12 -	2.16 11 -	2.57 **13** -	4.69 **24** -	5.81 **30** -	19.2	-
Planting 1987															
1993	6	1.06 5 -	1.95 9 -	2.19 10 -	3.20 15 -	3.26 15 -	2.13 10 -	1.92 9 -	1.65 8 -	1.70 8 -	0.83 4 -	0.58 3 -	1.12 5 -	21.6	0
1994	7	1.41 5 -	2.20 8 -	1.68 6 -	4.16 15 -	2.70 10 -	3.44 12 -	2.32 8 -	1.69 6 -	1.50 5 -	2.13 8 -	2.24 8 -	2.14 8 -	27.6	392
1995	8	1.93 10 -	0.92 5 -	0.78 4 **16**	0.75 4 **18**	0.79 4 **17**	0.58 3 -	0.66 3 -	1.33 7 -	2.55 13 -	2.35 **12** -	3.50 **18** -	3.12 **16** -	19.3	0
1996	**9**	**1.65** **8** -	**1.64** **8** -	**2.00** **9** -	**2.45** **12** -	**2.45** **12** -	**2.06** **10** -	**1.59** **8** -	**1.56** **7** -	**2.01** **10** -	**1.75** **8** -	**1.03** **5** -	**0.97** **5** -	21.1	0
1997	10	1.28 5 -	1.37 6 -	1.89 8 -	3.29 13 -	4.57 18 -	3.83 16 -	3.29 13 -	2.48 10 -	1.23 5 -	0.59 2 -	0.47 2 -	0.42 2 -	24.7	614
1998	11	0.46 2 -	0.53 2 -	0.37 1 **13**	0.46 2 **13**	0.41 2 **14**	0.93 4 -	0.72 3 -	4.75 18 -	2.59 10 -	3.73 **14** -	5.53 **21** -	5.72 **22** -	26.2	

Remark :
- 1st line: monthly yield (t FFB/ha)
- 2nd line: % of the year production
- 3rd line: negative impact (% / 100 mm of water deficit cumulated during critical period 1)
- [shaded box]: potential

Table 3 - Climatic observations.

	Rainfall 1997 (mm)	Water deficit 1997 (mm)	Sunshine 1997 (h/day)	Global Radiation 1997 ($MJ/m^2/day$)	Global Radiation 1972 - 1994 (*) ($MJ/m^2/day$)
May	168	0	-	-	-
June	85	0	-	-	-
July	68	58	3.8	-	-
Augt	145	35	4.4	14.7	16.5
Sept.	41	87	0.7	10.1	15.3
Oct.	77	63	0.6	11.3	15.1
Nov.	187	53	3.9	14.2	14.7
Dec.	149	0	4.7	12.9	15.3

Rk : July 1997 : installation of Campbell Sunshine recorder at Libo Research Station.
August 1997 : installation of Gun Bellani Actinometer at Libo Research Station.
* : calculated by Lamade et al. (1996).

Table 4 - Simulation of production of the palms (Pekanbaru area)

Month	Week	Global Radiation	Rain	Soil Water Reserve	Water Deficit	Stomatal Conductance	A max**	FFB simulation	FFB simulation without haze ***	Difference
		MJ.m-2.d-1	mm	% of maximum *	mm	mm.s-1	umol.m-2.s-1	t/ha	t/ha	t/ha
Sep	1	13.2	20	0	7	4.25	18.8	0.2	0.4	-0.2
	2	11.4	25	0	10	4.25	18.8	0	0.4	-0.4
	3	10.0	0	0	35	1	7.0	0	0	
	4	6.7	0	0	35	1	7.0	0	0	
Oct	5	8.5	0	0	35	1	7.0	0	0	
	6	12.1	77	21	0	10	30.7	0.3	0.7	-0.4
	7	12.2	0	4	0	4.25	18.8	0.1	0.4	-0.3
	8	9.6	0	0	28	1	7.0	0	0	
	9	12.9	0	0	35	1	7.0	0	0	
Total:								0.6	1.9	-1.3

* : maximum= 200 mm
** : A max= maximum photosynthetic assimilation
*** : for a standard global radiation of 15.2 MJ.m-2.day-1

Table 5 - Oil extraction rate

	1993	1994	1995	1996	1997
September	24.2	24.3	23.3	23.7	23.1
October	24.1	24.4	23.5	24.0	22.1

Table 6 - Oil extraction rate and characteristics of bunches.

	1996		1997	
	Unripe (%)	OER (%)	Unripe (%)	OER (%)
August	10	23.7	23	23.5
September	11	23.7	12	23.1
October	11	24.0	15	22.1

Table 7 - Coefficients of correlation between OER and GR or SWR

Period	OER/GR	OER/SWR
Week 1 to 4	+ 0.82 ***	-
Week 5 to 12	-	+ 0.54 ***
Week 19 to 26	-	- 0.42 ***

*** significant with a probability of 0.1 %.

Table 8 - Coefficients of correlation between OER residues and SWR

Period	correlation
Week 8 to 9	+ 0.41 **
Week 17 to 20	- 0.36 *

* significant with a probability of 5 %.
** significant with a probability of 1 %.

Table 9 - OER and characteristics of the crop processed

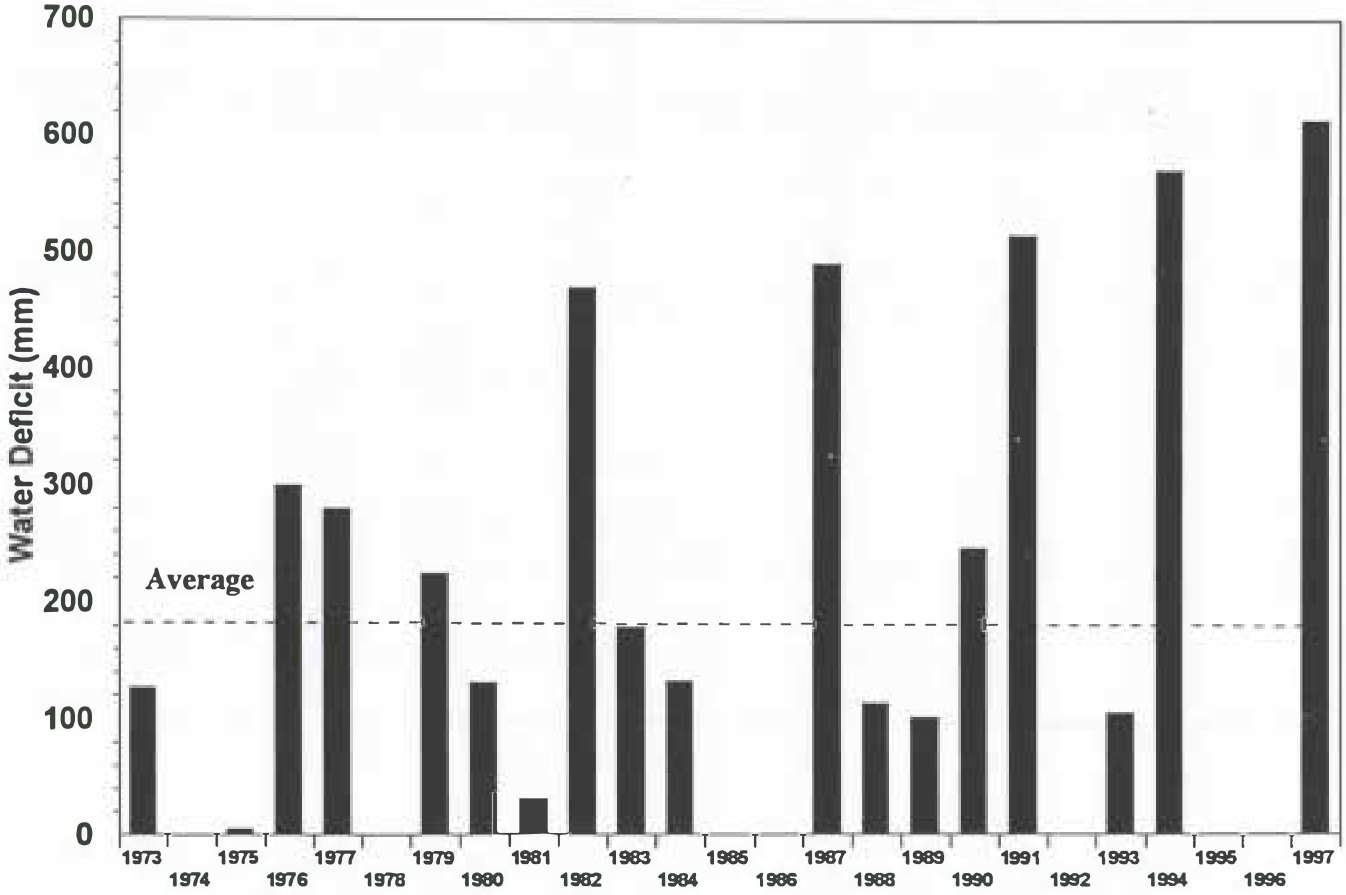
	Period	OER mini (week) (%)	Unripe Bunches (%)	bad pollinated Bunches (%)	Young crop 2-4 years (%)	Observation
Pic 1	May 94	22.3	7	15	?	bad pollination
	June	22.1	6	13	?	bad pollination
Pic 2	March 95	23.3	17	11	?	Unripe bunches
	April	23.0	16	9	?	(bad pollination)
Pic 3	Augt 95	22.3	8	13	?	bad pollination
	Sept	22.9	9	14	?	bad pollination
	Oct	23.3	10	14	?	bad pollination
Pic 4	July 96	22.2	15	3	22	Unripe bunches
Pic 5	Jan 97	23.2	12	2	37	Unripe bunches
	March	22.7	16	5	42	and
	April	23.1	15	10	33	Young crop
General Average(*)		24.0 (1)	10 (1)	7 (1)	26 (2)	

(*) : Average of the records during the following periods :

(1) : August 1993 - December 1997.

(2) : January 1996 - December 1997.

Fig.1 - Lampung: water deficit



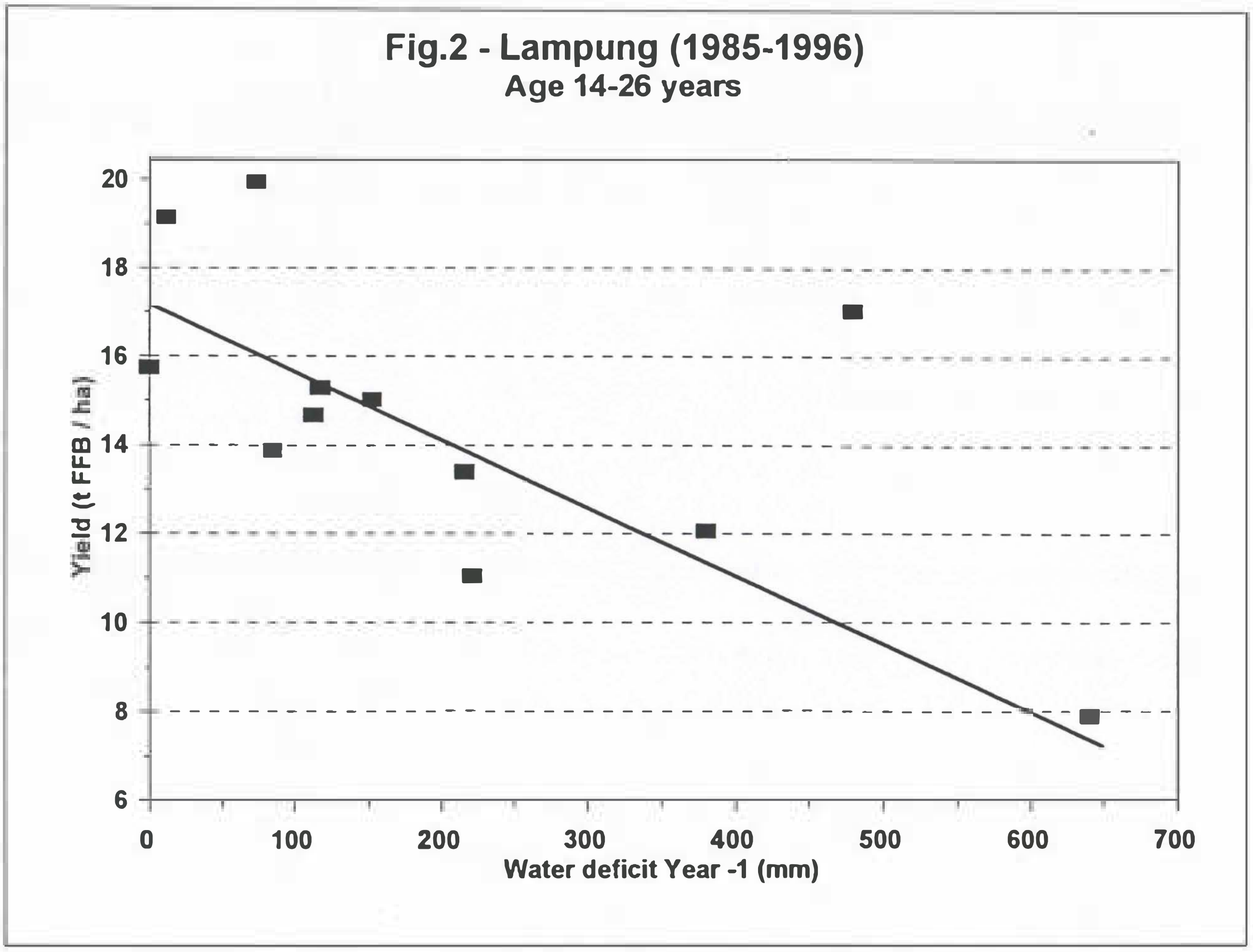


Fig.2 - Lampung (1985-1996)
Age 14-26 years
Yield (t FFB / ha)
20
18
16
14
12
10
8
6
0
100
200
300
400
500
600
700
Water deficit Year -1 (mm)

Fig.3 - Pangkalan Panji estate
Planting 1975

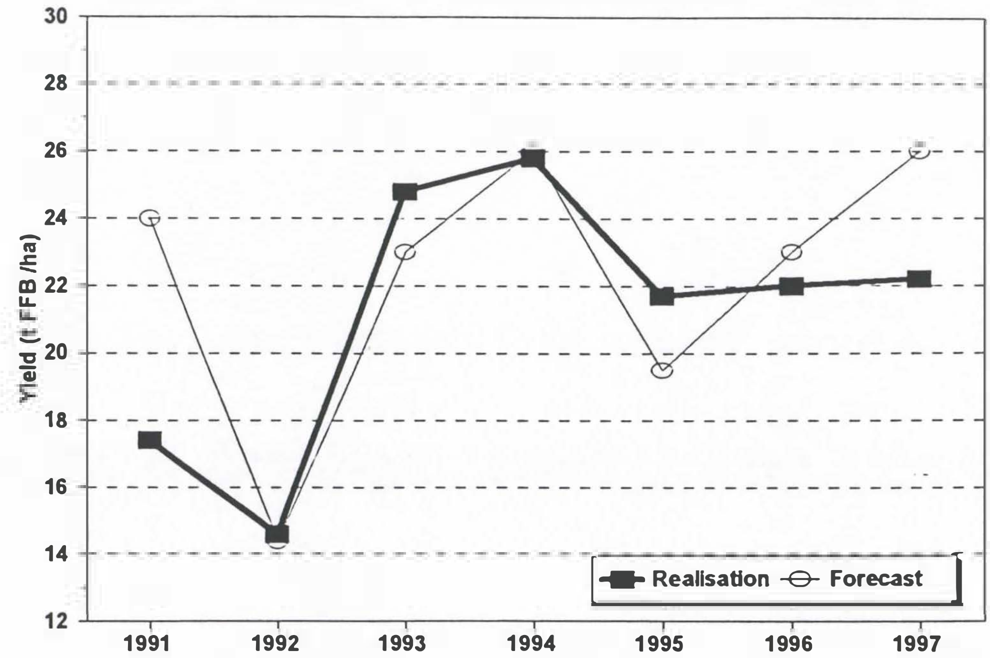
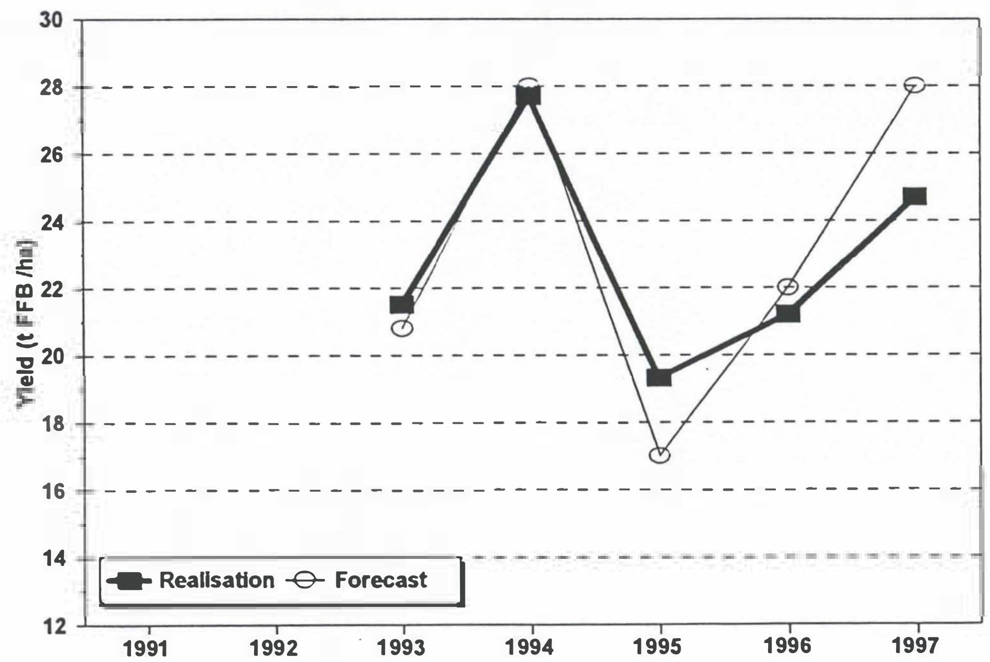


Fig.4 - Pangkalan Panji estate
Planting 1987



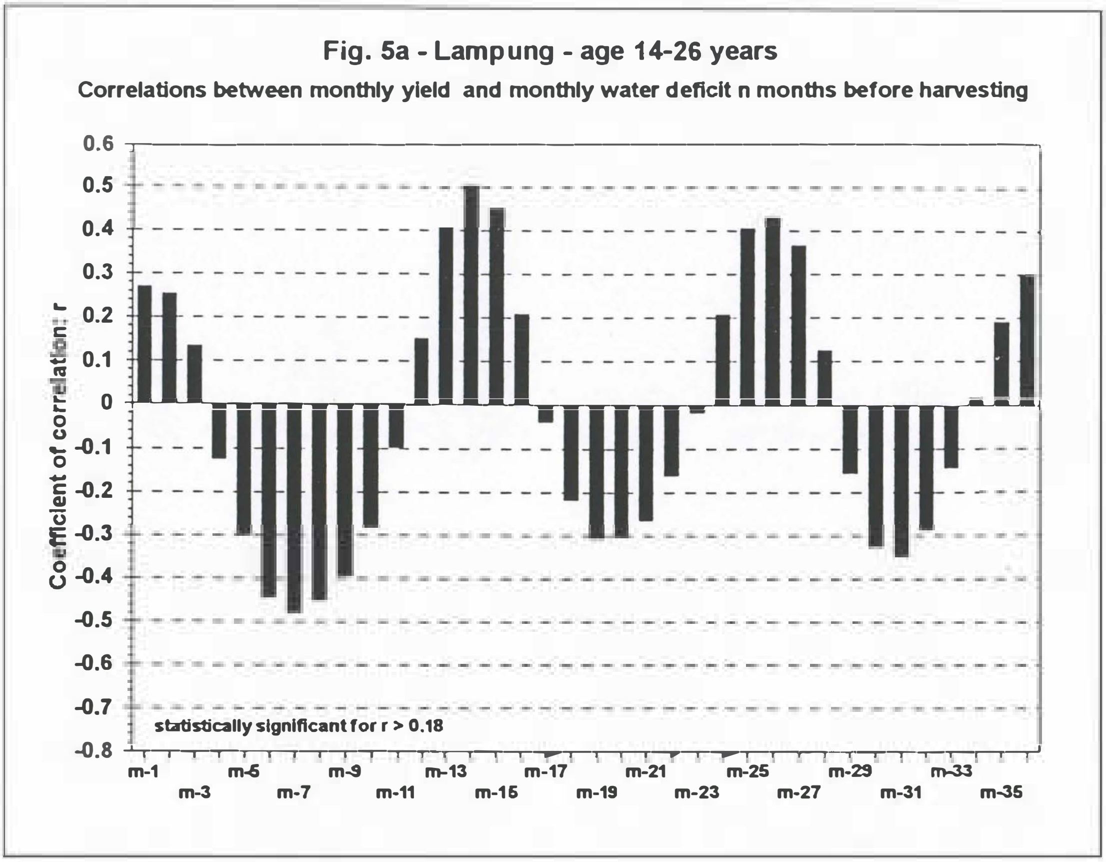


Fig. 5a - Lampung - age 14-26 years
Correlations between monthly yield and monthly water deficit n months before harvesting
Coefficient of correlation: r
statistically significant for r > 0.18
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
m-1
m-3
m-5
m-7
m-9
m-11
m-13
m-15
m-17
m-19
m-21
m-23
m-25
m-27
m-29
m-31
m-33
m-35

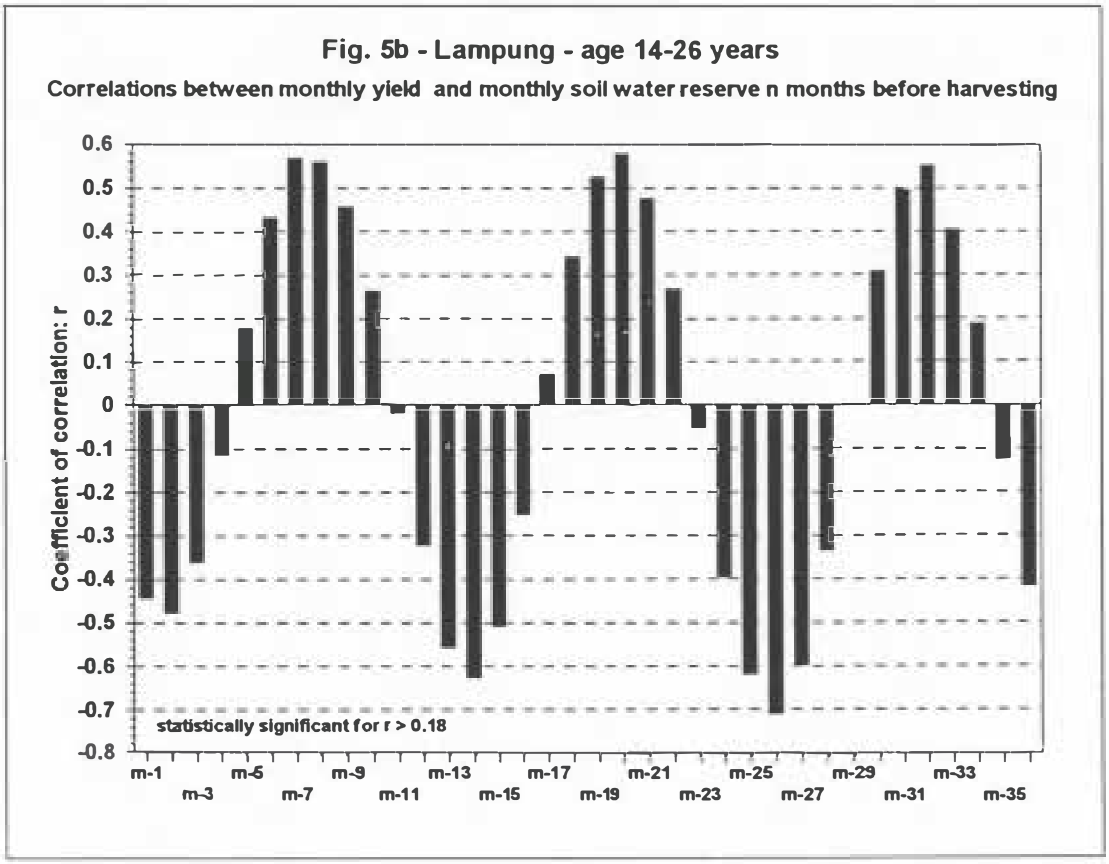
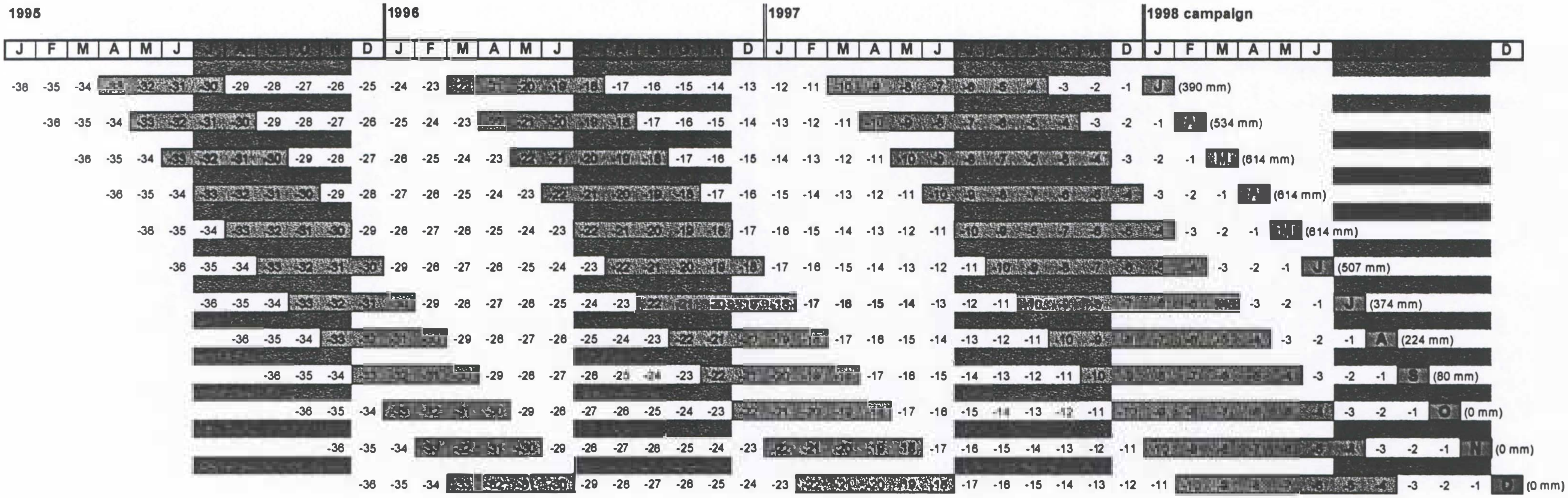


Fig. 5b - Lampung - age 14-26 years
Correlations between monthly yield and monthly soil water reserve n months before harvesting
Coefficient of correlation: r
statistically significant for r > 0.18
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
m-1
m-3
m-5
m-7
m-9
m-11
m-13
m-15
m-17
m-19
m-21
m-23
m-25
m-27
m-29
m-31
m-33
m-35

Fig. 6 - Sensitive period and coincidence with possible drought depending on month of harvesting

Example in Lampung



Month usually susceptible of water stress in Lampung

Period of sensivity of the palms for a specified month

Harvesting month

(390 mm) Total water deficit (from month -4 to month -10) supported by bunches harvested during the corresponding month

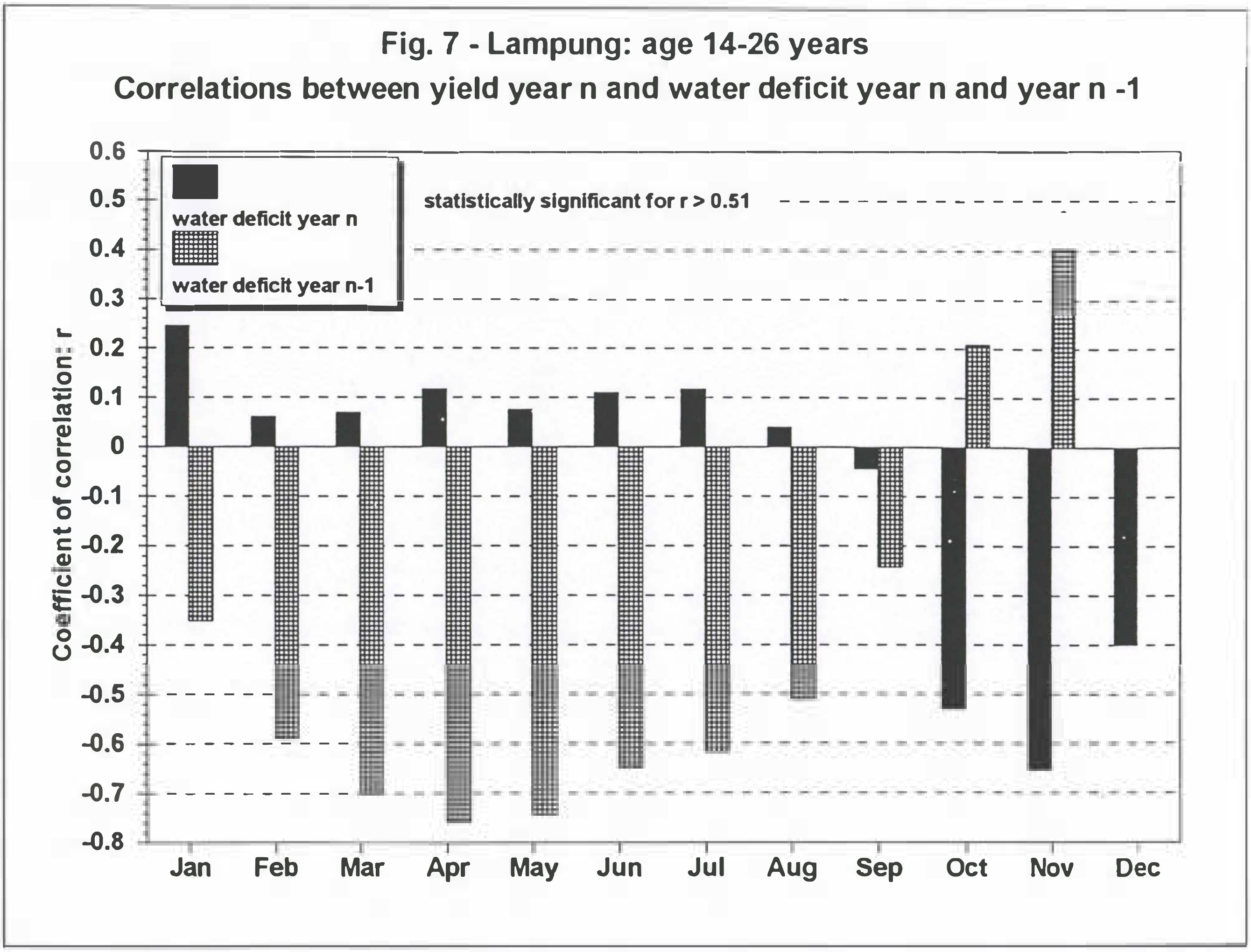


Fig. 7 - Lampung: age 14-26 years
Correlations between yield year n and water deficit year n and year n -1
water deficit year n
water deficit year n-1
statistically significant for r > 0.51
Coefficient of correlation: r
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

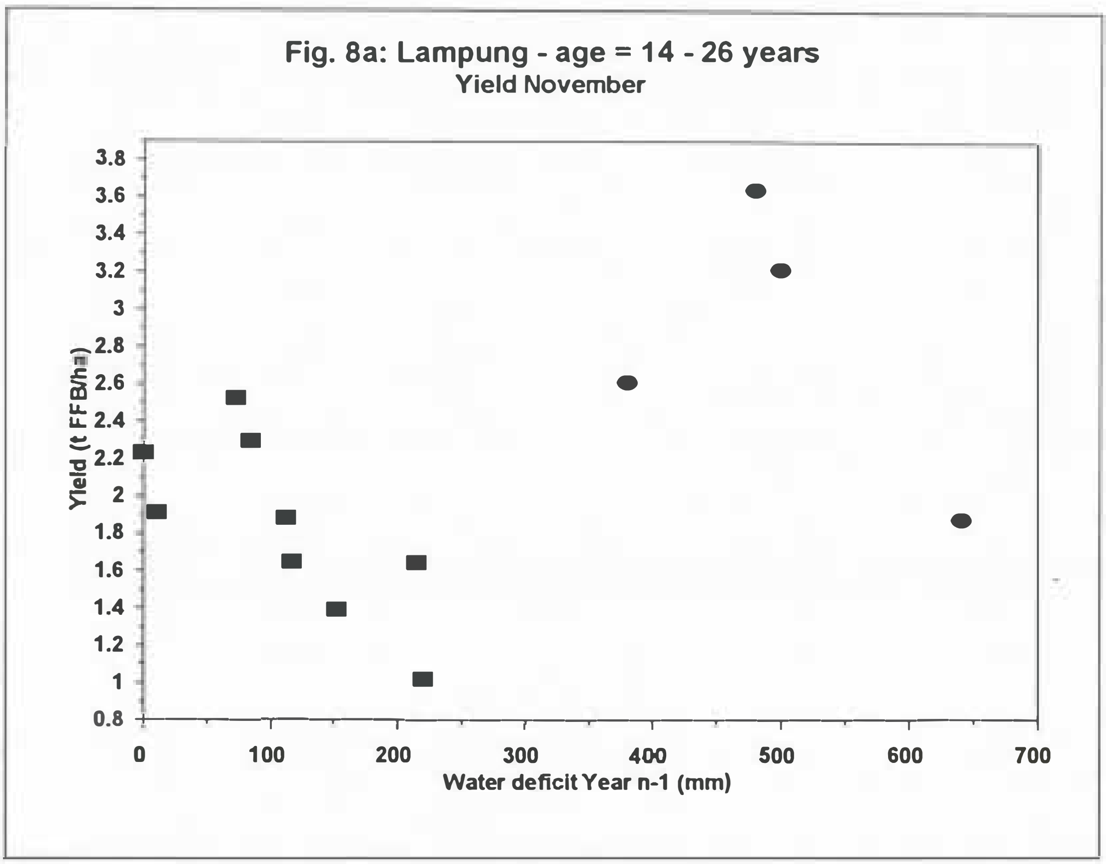


Fig. 8a: Lampung - age = 14 - 26 years
Yield November
Yield (t FFB/ha)
Water deficit Year n-1 (mm)
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0
100
200
300
400
500
600
700

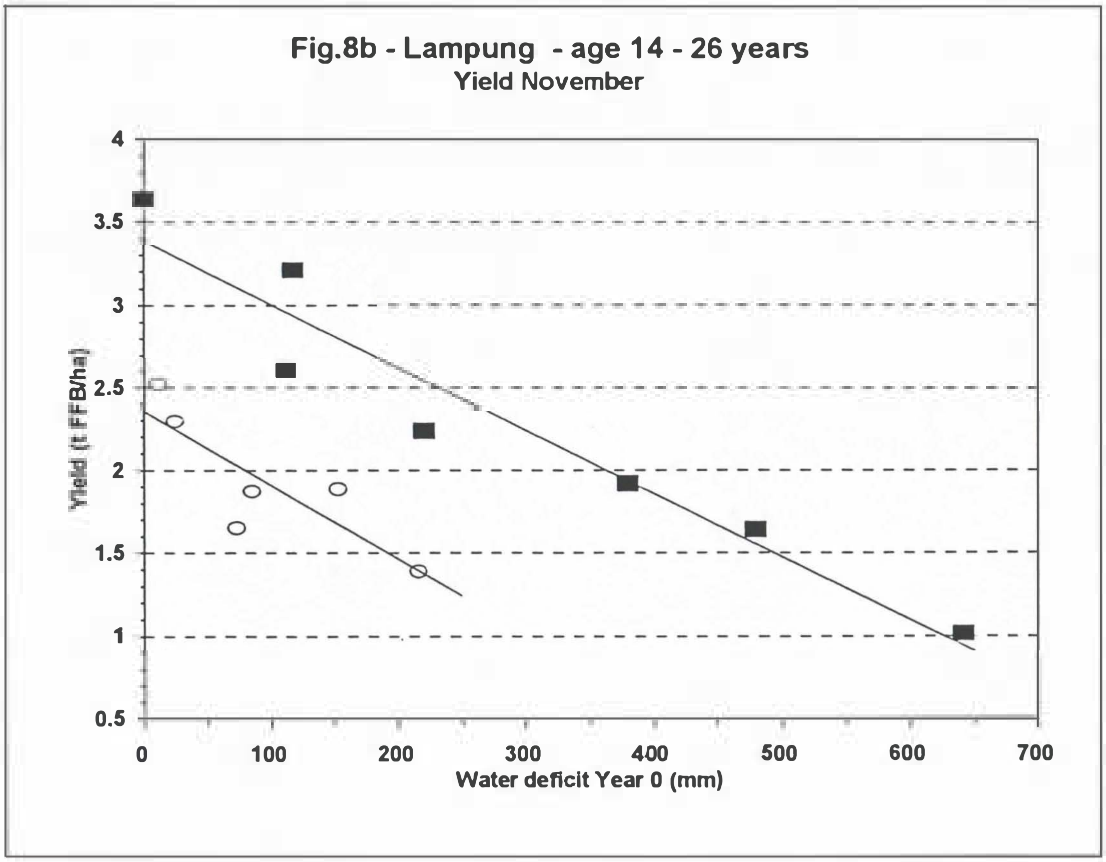


Fig.8b - Lampung - age 14 - 26 years
Yield November
Yield (t FFB/ha)
Water deficit Year 0 (mm)
4
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700

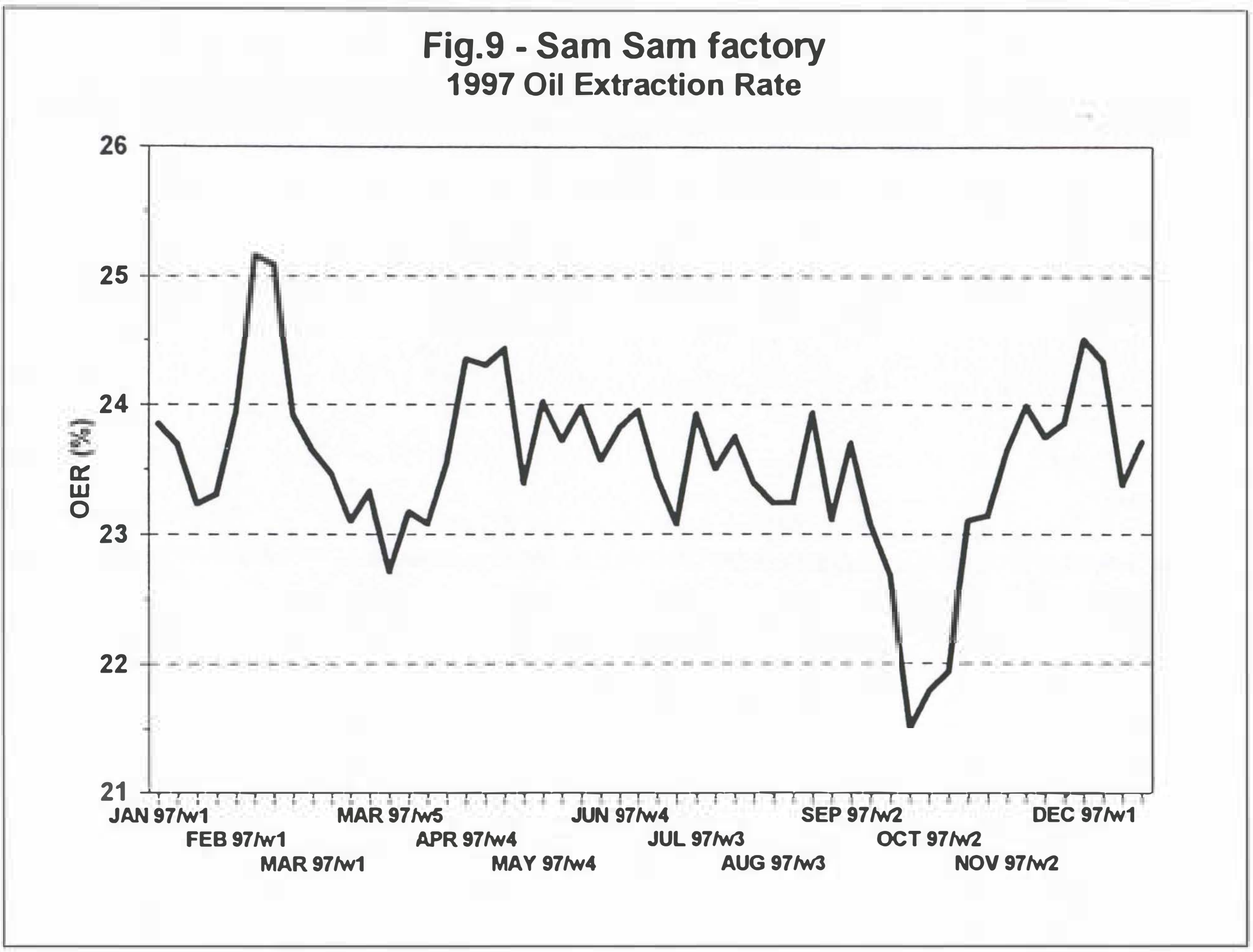


Fig.9 - Sam Sam factory
1997 Oil Extraction Rate
26
25
24
23
22
21
OER (%)
JAN 97/w1
FEB 97/w1
MAR 97/w1
MAR 97/w5
APR 97/w4
MAY 97/w4
JUN 97/w4
JUL 97/w3
AUG 97/w3
SEP 97/w2
OCT 97/w2
NOV 97/w2
DEC 97/w1

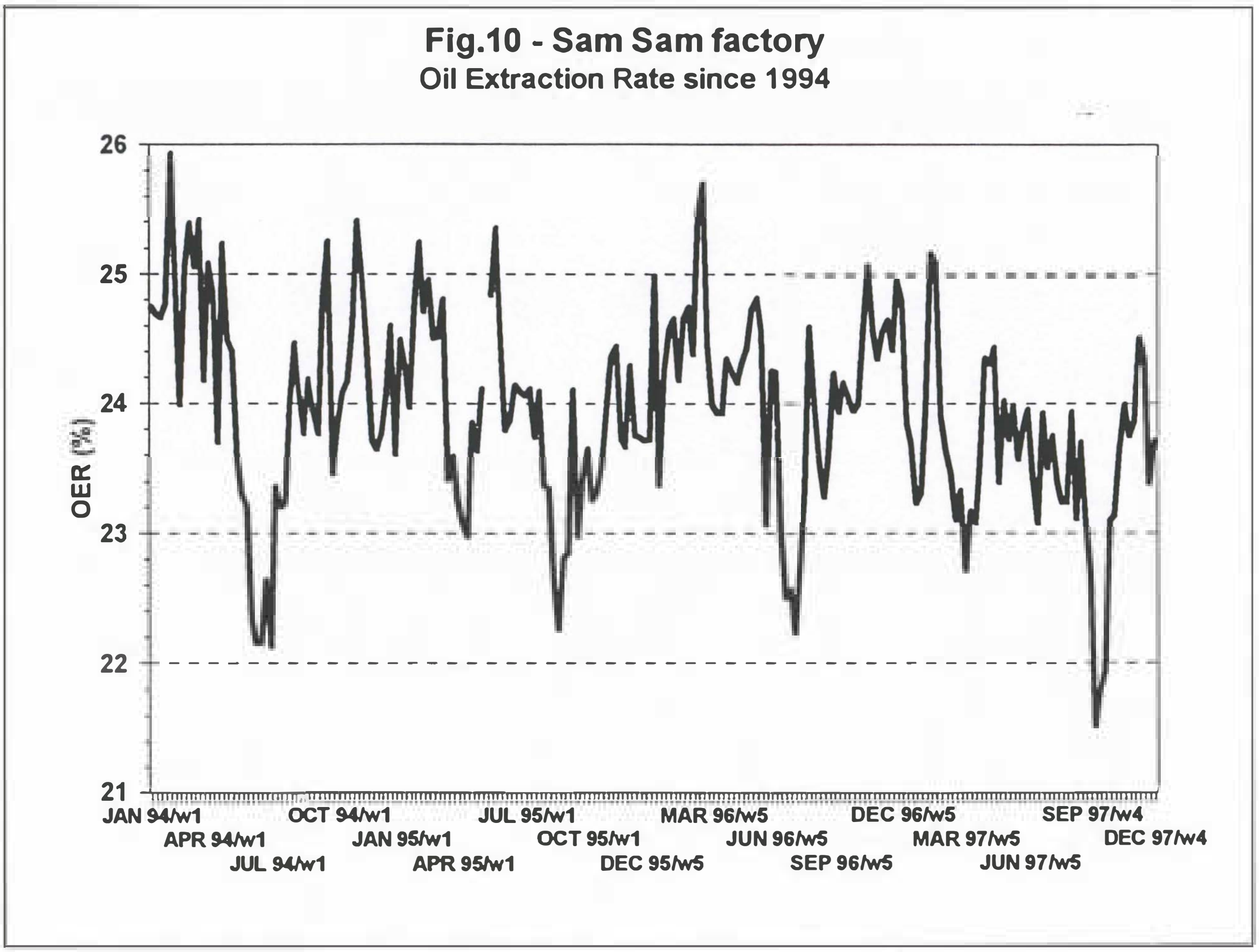


Fig.10 - Sam Sam factory
Oil Extraction Rate since 1994
26
25
24
23
22
21
OER (%)
JAN 94/w1
APR 94/w1
JUL 94/w1
OCT 94/w1
JAN 95/w1
APR 95/w1
JUL 95/w1
OCT 95/w1
DEC 95/w5
MAR 96/w5
JUN 96/w5
SEP 96/w5
DEC 96/w5
MAR 97/w5
JUN 97/w5
SEP 97/w4
DEC 97/w4

Fig. 11a - Sam Sam

Correlations between weekly OER and global radiation n weeks before harvesting

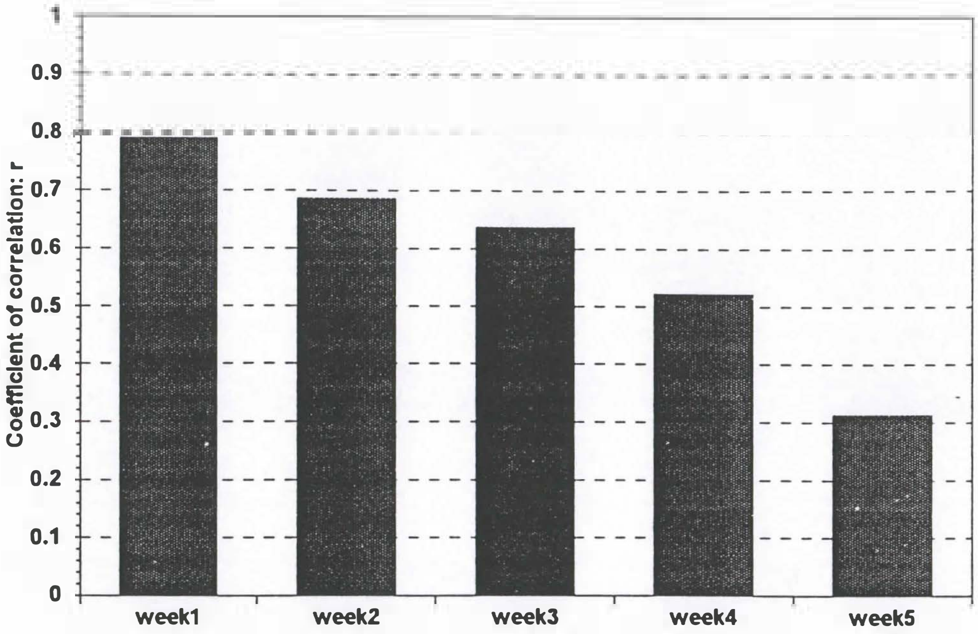
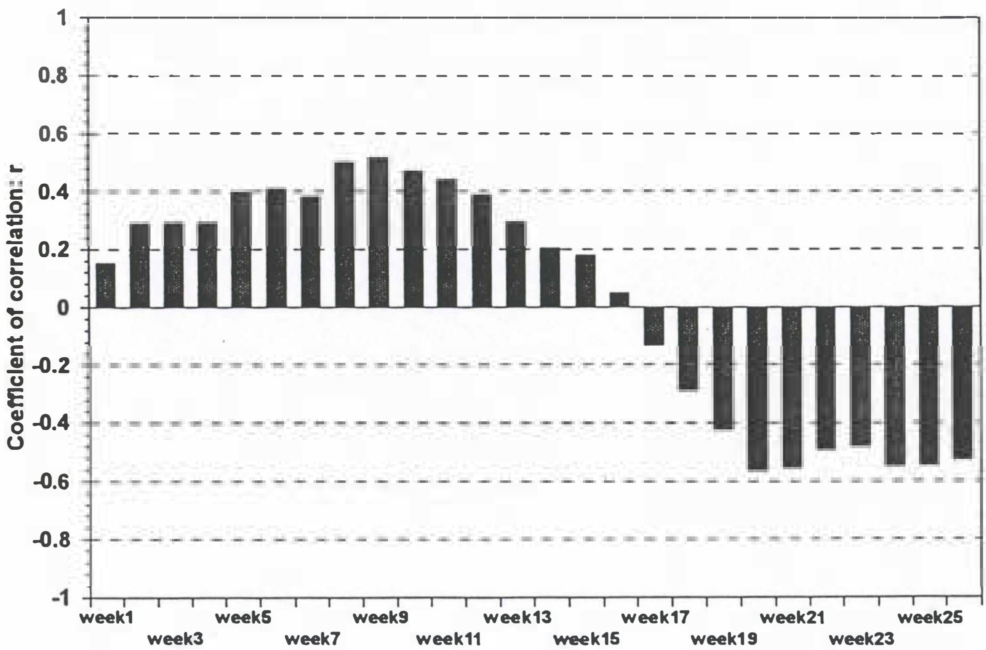


Fig. 11b - Sam Sam

Correlations between weekly OER and soil water reserve n weeks before harvesting



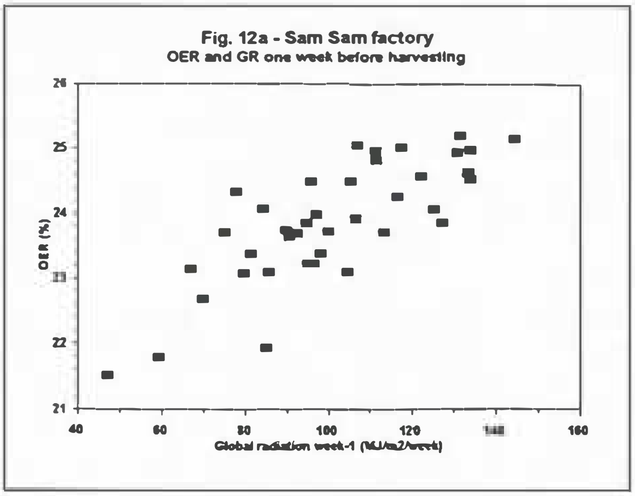


Fig. 12a - Sam Sam factory
OER and GR one week before harvesting
OER (%)
Global radiation week-1 (MJ/m2/week)

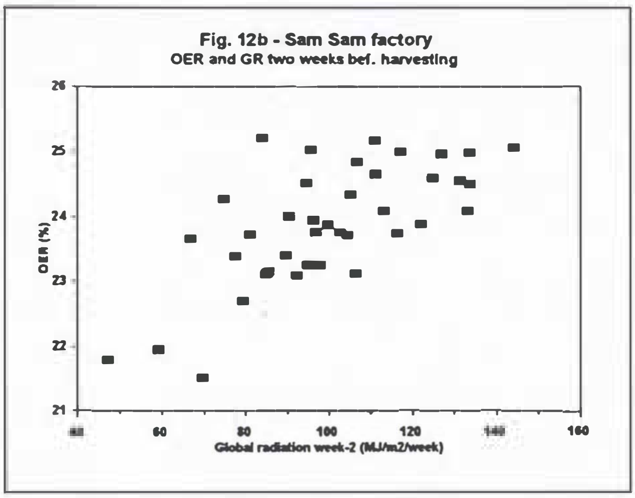


Fig. 12b - Sam Sam factory
OER and GR two weeks bef. harvesting
OER (%)
Global radiation week-2 (MJ/m2/week)

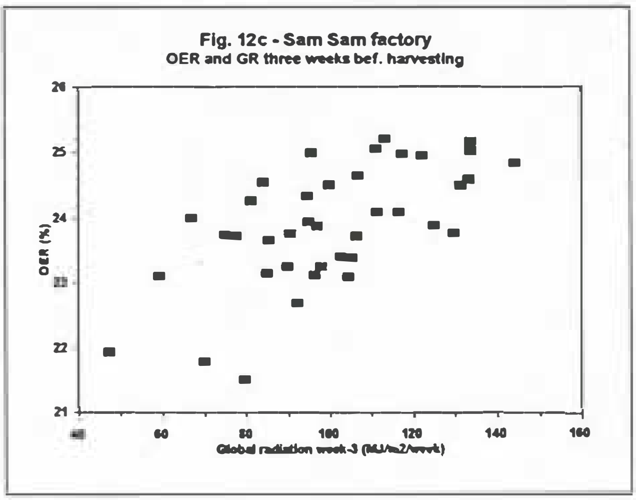


Fig. 12c - Sam Sam factory
OER and GR three weeks bef. harvesting
OER (%)
Global radiation week-3 (MJ/m2/week)

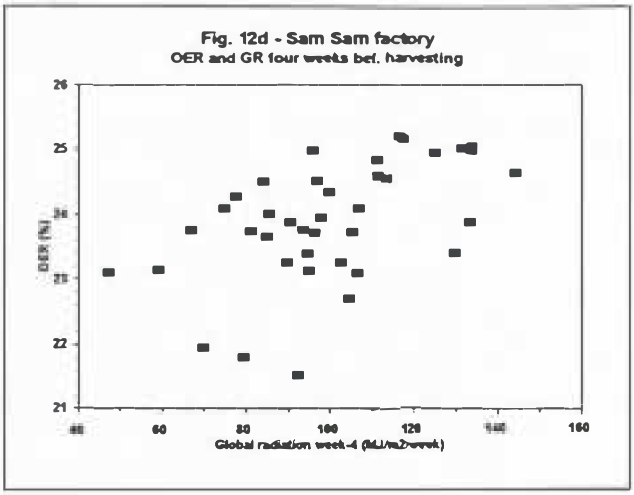


Fig. 12d - Sam Sam factory
OER and GR four weeks bef. harvesting
Global radiation week-4 (MJ/m2/week)

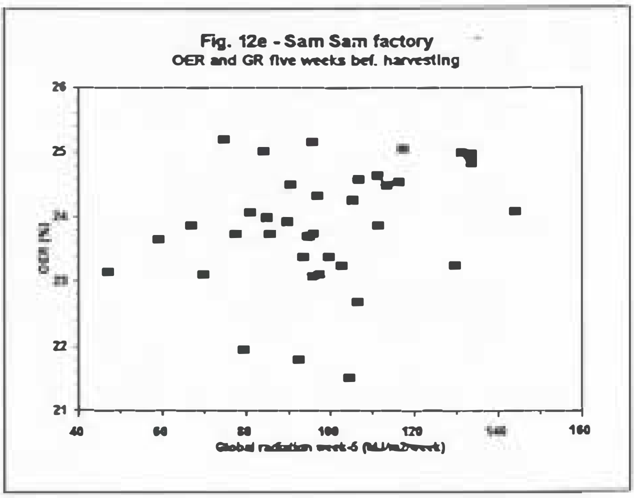


Fig. 12e - Sam Sam factory
OER and GR five weeks bef. harvesting
Global radiation week-5 (MJ/m2/week)

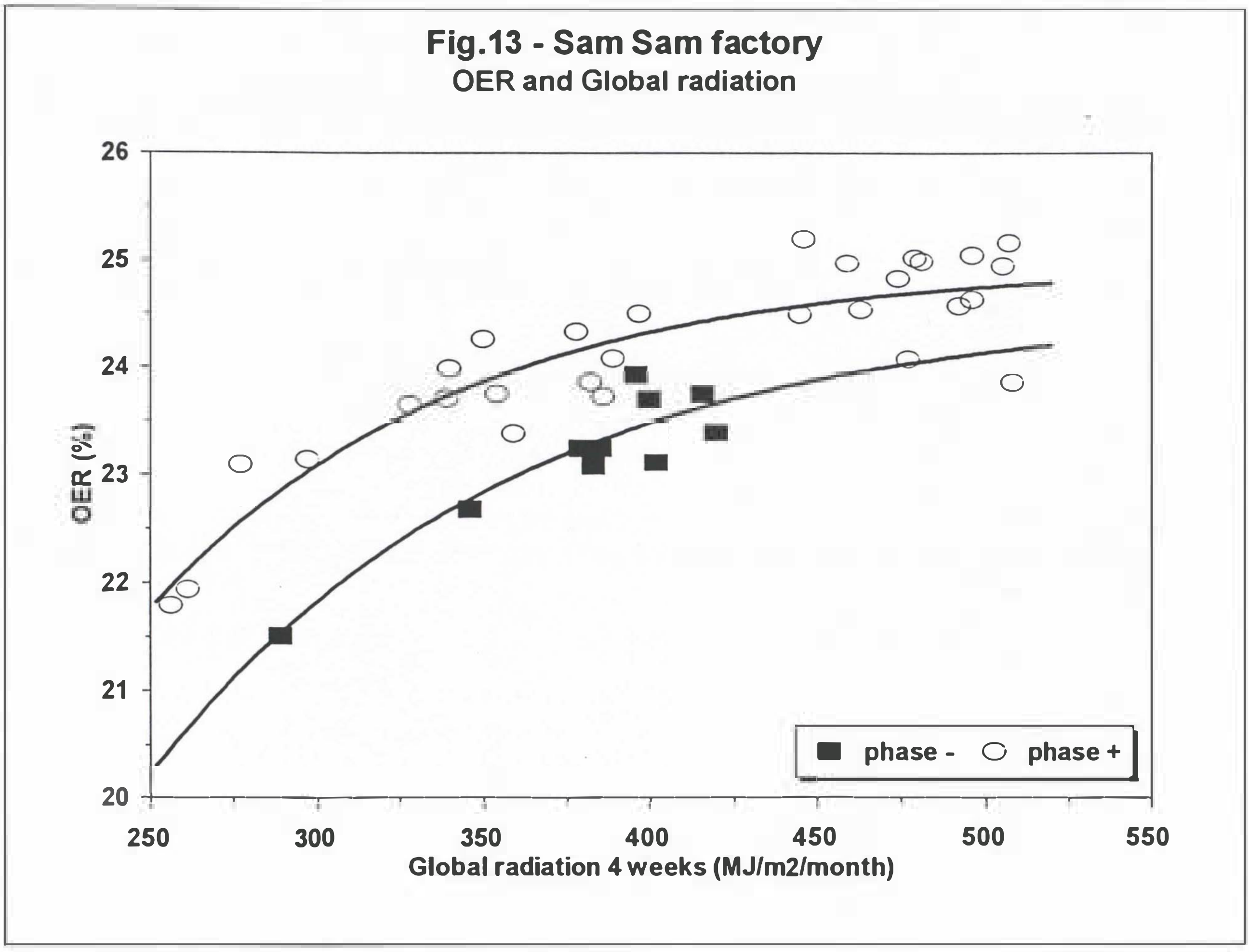


Fig.13 - Sam Sam factory
OER and Global radiation
OER (%)
26
25
24
23
22
21
20
250
300
350
400
450
500
550
Global radiation 4 weeks (MJ/m2/month)
phase -
phase +

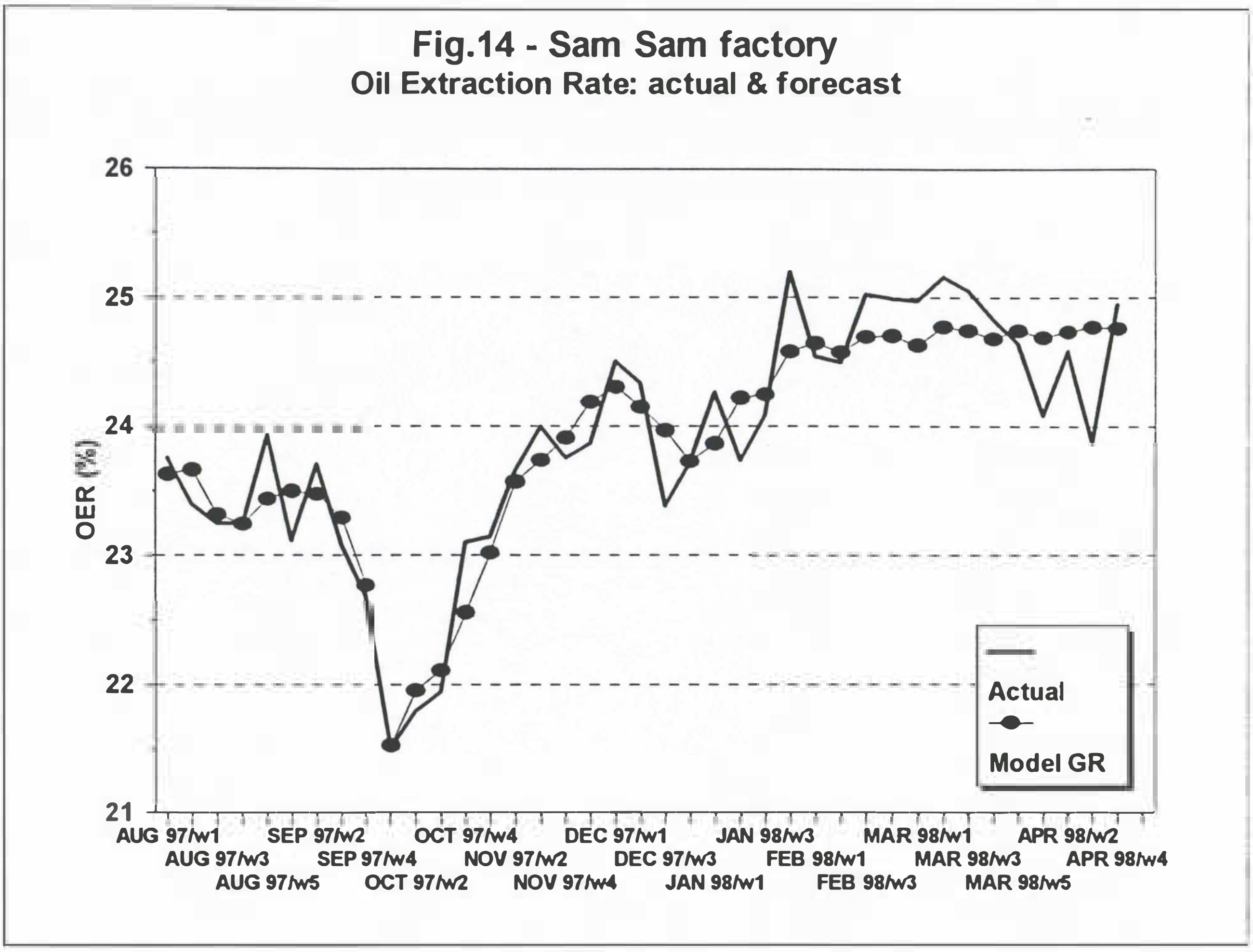
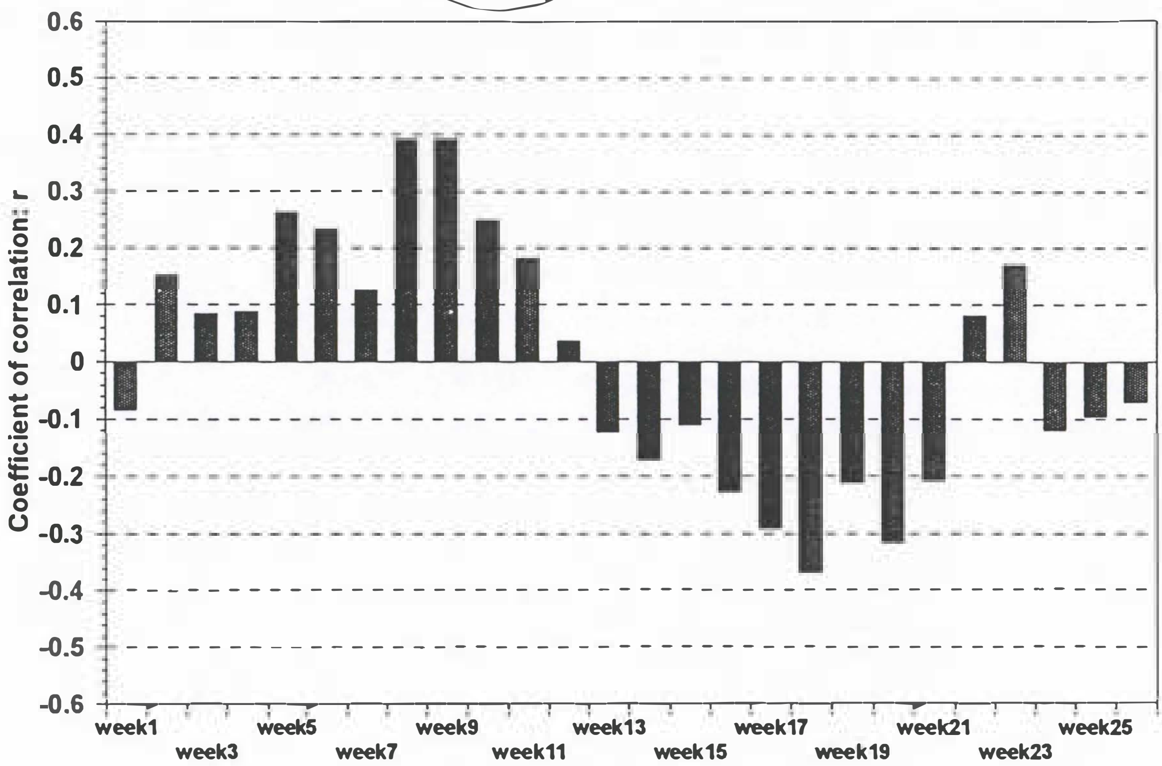


Fig.14 - Sam Sam factory
Oil Extraction Rate: actual & forecast
26
25
24
23
22
21
OER (%)
Actual
Model GR
AUG 97/w1
AUG 97/w3
AUG 97/w5
SEP 97/w2
SEP 97/w4
OCT 97/w2
OCT 97/w4
NOV 97/w2
NOV 97/w4
DEC 97/w1
DEC 97/w3
JAN 98/w1
JAN 98/w3
FEB 98/w1
FEB 98/w3
MAR 98/w1
MAR 98/w3
MAR 98/w5
APR 98/w2
APR 98/w4

Fig. 15 - Sam Sam

Correlations between weekly residues of OER and soil water reserve n weeks before harvesting



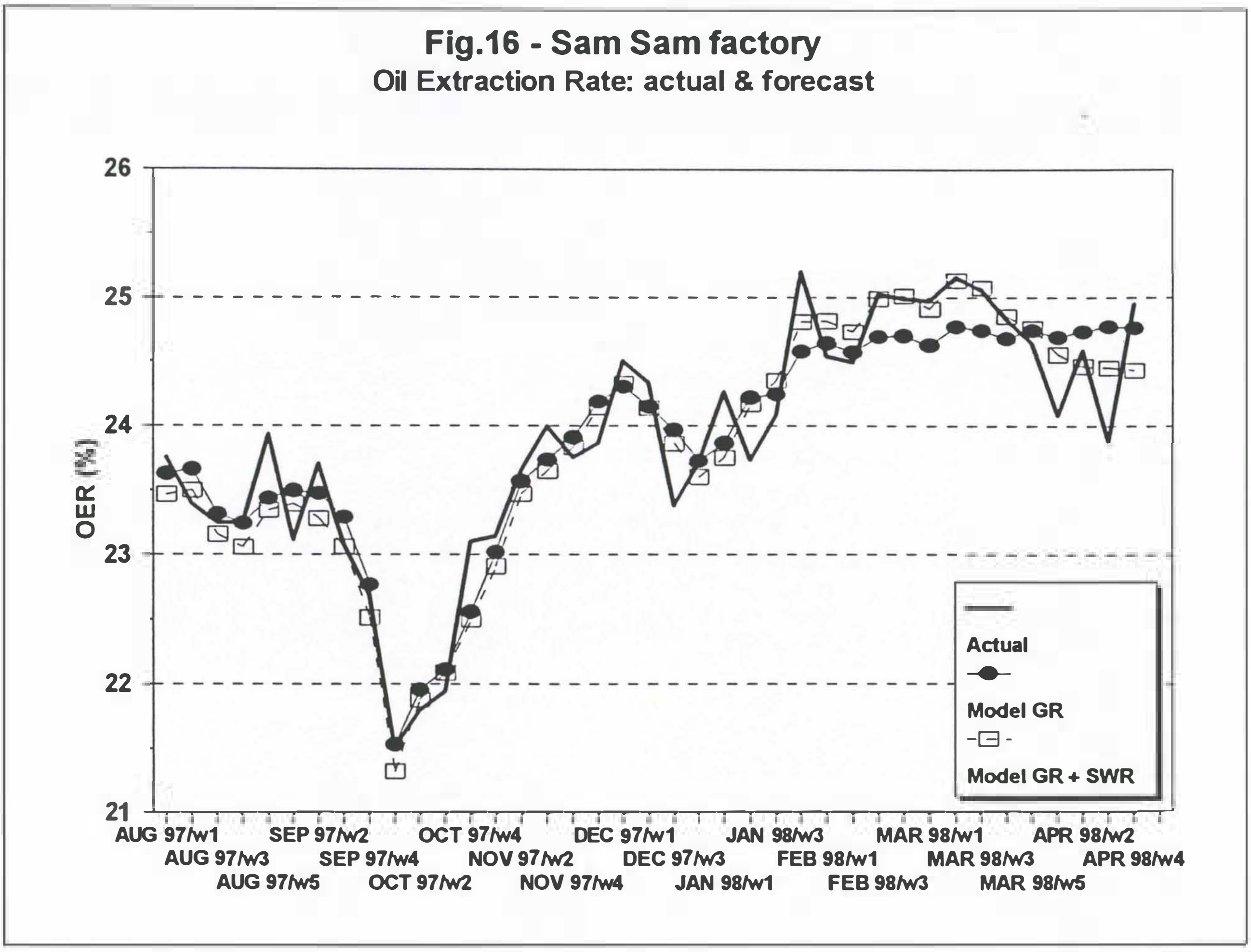


Fig.16 - Sam Sam factory
Oil Extraction Rate: actual & forecast
26
25
24
23
22
21
OER (%)
Actual
Model GR
Model GR + SWR
AUG 97/w1
AUG 97/w3
AUG 97/w5
SEP 97/w2
SEP 97/w4
OCT 97/w2
OCT 97/w4
NOV 97/w2
NOV 97/w4
DEC 97/w1
DEC 97/w3
JAN 98/w1
JAN 98/w3
FEB 98/w1
FEB 98/w3
MAR 98/w1
MAR 98/w3
MAR 98/w5
APR 98/w2
APR 98/w4

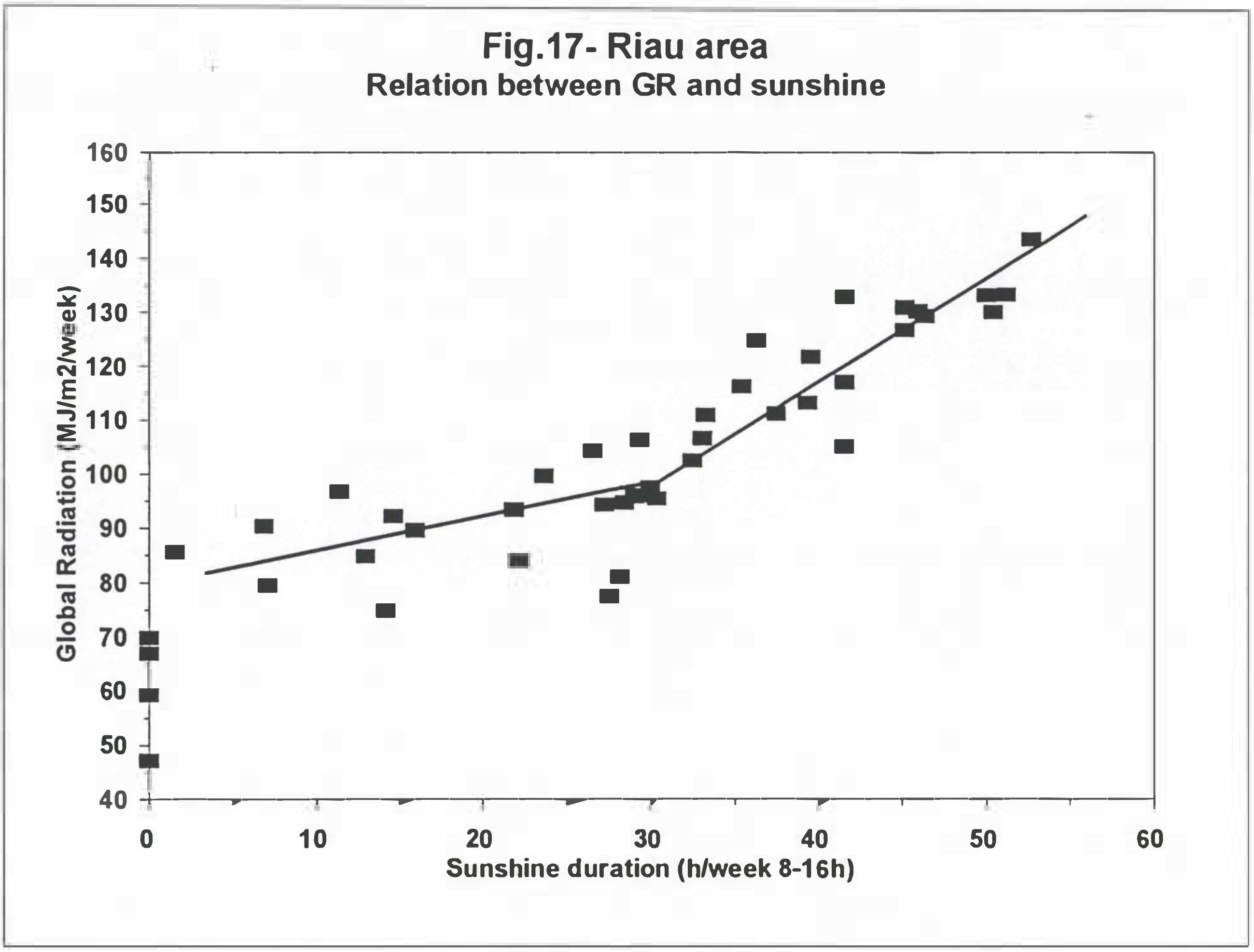


Fig.17- Riau area
Relation between GR and sunshine
Global Radiation (MJ/m2/week)
160
150
140
130
120
110
100
90
80
70
60
50
40
0
10
20
30
40
50
60
Sunshine duration (h/week 8-16h)

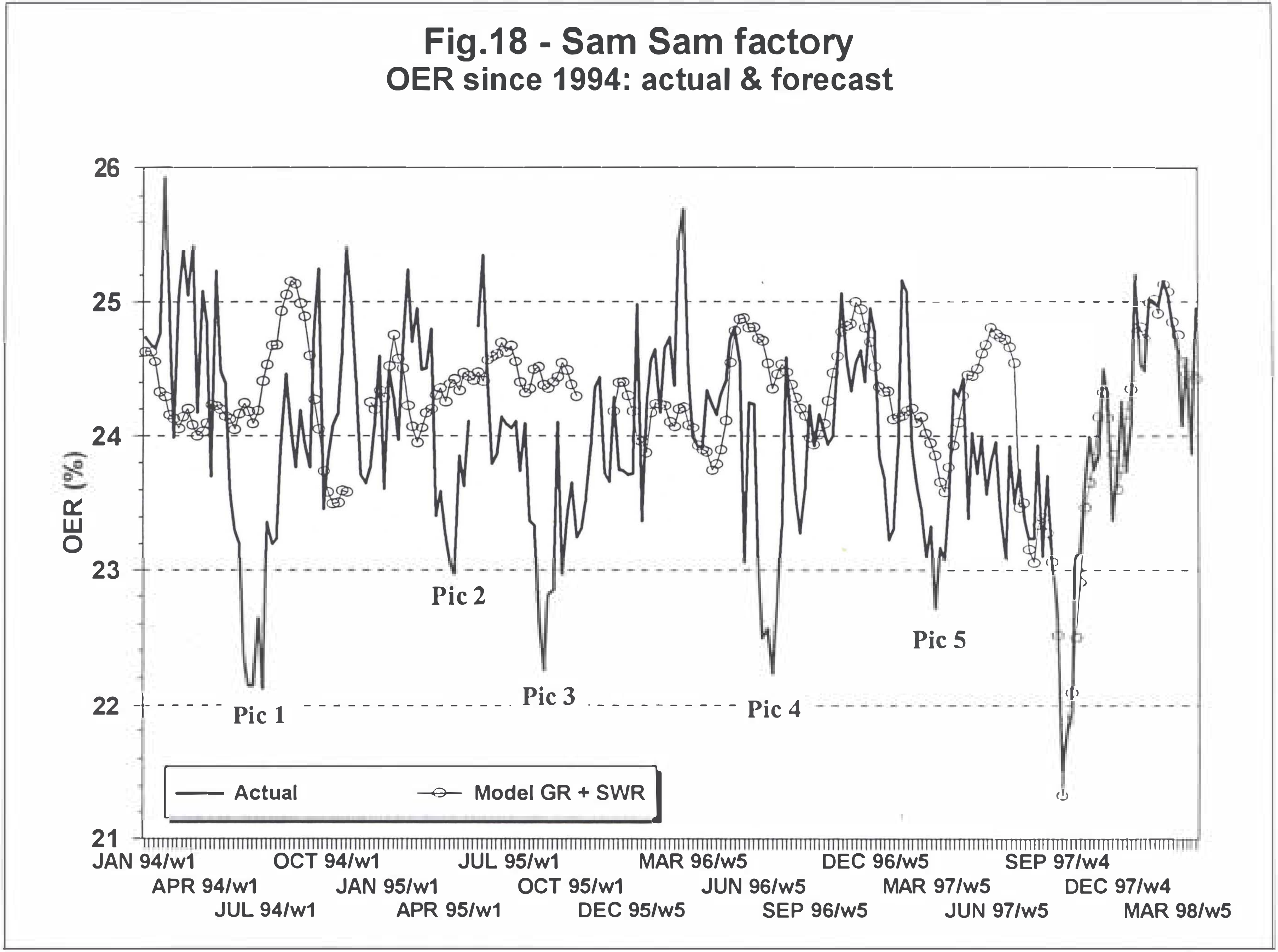


Fig.18 - Sam Sam factory
OER since 1994: actual & forecast
OER (%)
26
25
24
23
22
21
Pic 1
Pic 2
Pic 3
Pic 4
Pic 5
Actual
Model GR + SWR
JAN 94/w1
APR 94/w1
JUL 94/w1
OCT 94/w1
JAN 95/w1
APR 95/w1
JUL 95/w1
OCT 95/w1
DEC 95/w5
MAR 96/w5
JUN 96/w5
SEP 96/w5
DEC 96/w5
MAR 97/w5
JUN 97/w5
SEP 97/w4
DEC 97/w4
MAR 98/w5